Ontario

WATER QUANTITY RESOURCES OF ONTARIO

Ontario

WATER QUANTITY RESOURCES OF ONTARIO

ACKNOWLEDGEMENTS

This report is the product of the constructive efforts of many individuals and agencies whose active cooperation was much appreciated. In particular the support of Mr. J.R. Sloan, Deputy Minister, Ministry of Natural Resources, throughout the production of the document was greatly appreciated.

The Steering Committee for the project included:

Mr. H.A. Clarke, Ministry of Natural Resources (MNR), Chairman
Mr. D.N. Jeffs, Ministry of the Environment (MOE)
Mr. M.R. Garrett, MNR
Mr. U. Sibul, MOE
Mr. R.P. Milligan, MNR, Project Manager and Editor.

A number of MNR staff and staff in the other provincial ministries deserve special mention.

Mr. R.B. Chang, MNR
Mr. T.J. Yakutchik, MOE
Mr. R.M. Odell, MNR
Mr. A.E. Kibedi, Ministry of Transportation and Communications (MTC)
Mr. D.L. Strelchuk, MNR.
Mr. T.N. Nastich, MNR

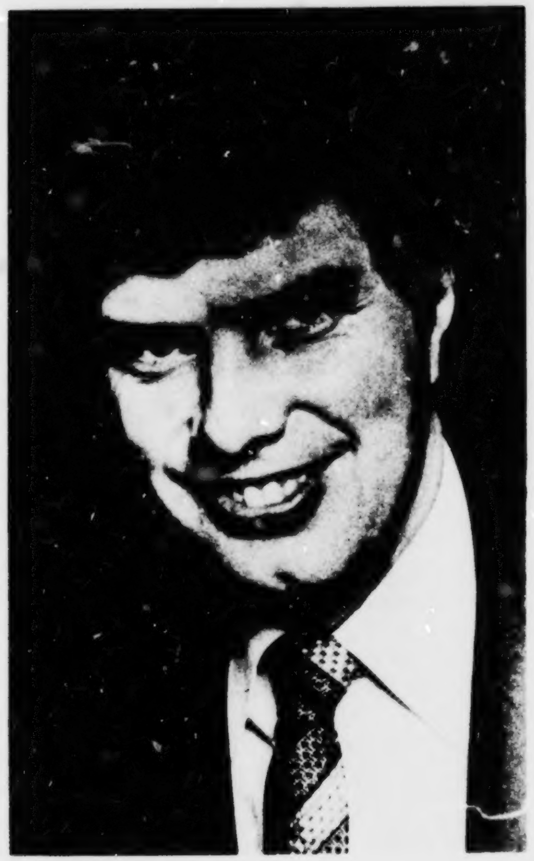
Acres Consulting Services Limited of Niagara Falls, Ontario carried out the project. The following team was involved directly in the preparation of the document

Dr. I.K. Hill, Project Manager
Mr. R.W. McLean, Project Co-ordinator.
Mr. D.G. Judge, Surface Water Research
Mr. R.E.J. Leech, Mr. J.P. Phimister (Gartner Lee Associates Limited, Markham, Ontario), Ground Water Research
Mr. M.J. Sandoz, Water Use Research
Mr. P. Bowen, Graphic Design
Mr. M.R. Reutter, Ms. S.S. Letourneau, Graphic Production
Mr. J. McConnell, Artist

Printing - G. Lyon's Litho Limited, Fort Erie, Ontario

ISBN 0-7743-9063-8
MNR - PUB 5932
JUNE 1984

La version française de cette publication sera disponible sous peu.



FOREWORD

I am pleased to introduce the Water Quantity Resources of Ontario. This 72-page publication is the first comprehensive review of Ontario's water quantity resources. With 26 colour maps and various diagrams, this book reviews the present supply and current use of surface and ground water resources, and the possible future demands for the resource.

I would like to congratulate the staff in my ministry for the co-ordination and production of such a timely and useful document. In addition, I would like to thank the staff in the Ministries of the Environment and Transportation and Communications, Ontario Hydro, and the federal Department of the Environment for their assistance with this publication.

Ontario is fortunate to have an abundance of water resources. Most people would probably be surprised to learn that Ontario has about 228,000 lakes. Each year the total river flow in Ontario is about 10 per cent of Canada's total and 1 per cent of the world's total.

This publication is designed to show the people of Ontario how important our water resources are to this province. In 1981, 57 million cubic metres per day of water were used in Ontario -- at our homes, farms and industries. That works out to about 6,600 litres per day for each Ontario resident. Water generates about one-third of Ontario's electricity. Ontario ports handle about 74 million tonnes of goods on the St. Lawrence Seaway and Great Lakes annually. Ontario also boasts some of the finest fresh water fishing and boating in the world.

The demand for Ontario's water continues to grow -- both from within the province and other parts of North America. There are concerns in Ontario about the impact of this ever-increasing demand. For example, projected water demands in Canada and the United States could lower the levels of some of the Great Lakes by 12 to 34 centimetres by the year 2035. This could result in significant losses in hydroelectric power generation, cargo shipping capacity, as well as the adverse environmental impact on nearshore and wetlands areas, which are vital to our fish and wildlife.

The Water Quantity Resources of Ontario is designed to increase our understanding of the importance of our water resources -- and to assist all of us in making decisions that will ensure the wise use of this water resource for years to come.

Alan W. Pope
Minister of Natural Resources
June 1984

Numbers refer to subsections in Table of Contents

Table of Contents

Page

1 – Ontario: An Overview 6
2 – Ontario's Water and Its Use 8

Surface Water Resources

Introduction 13
3 – Drainage Basins 14
4 – Mean Annual Precipitation 16
5 – Mean Annual Snowfall 18
6 – Monthly Distribution of Precipitation 20
7 – Mean Annual Lake Evaporation and Evapotranspiration 22
8 – Freeze-up and Breakup of Lakes and Rivers 24
9 – Mean Annual Runoff 26
10 – Monthly Distribution of Runoff 28
11 – Mean Annual River Flows 30
12 – Seasonal River Flows 32
List of References 34

Ground Water Resources

Introduction 37
13 – Bedrock Geology 38
14 – Ground Water Yields from Bedrock 40
15 – Surficial Geology 42
16 – Ground Water Yields from Overburden 44
17 – Ground Water Contributions to Streamflow 46
List of References 48

Water Use

Introduction 51
18 – Municipal Water Supply 52
19 – Municipal Treated Wastewater 54
20 – Total Withdrawals and Consumption 56
21 – Hydroelectric Power 60
22 – Commercial Shipping 62
23 – Water-Oriented Recreation and Tourism 64
24 – Cottaging 66
25 – Fish and Wildlife 68
26 – Ontario's Future Use of Water 70
List of References 71

1 – Ontario: An Overview

Ontario is a province of contrasts with

- densely populated southern urban centres and sparsely populated settlements on Hudson Bay
- highly developed agricultural areas, dense forest, muskeg and tundra
- popular summer cottage areas and remote fishing and hunting camps
- recreational water activities and international commercial shipping.

Ontario's development has always been linked closely to its water resources. The 5,300 kilometres (km) of shoreline along four of the Great Lakes and the St. Lawrence River provide excellent commercial shipping opportunities between major industrial centres in the province and access to international ports. Industrial development has therefore been concentrated around the Great Lakes.

ONTARIO
0 500 1000 1500
Kilometres

1.1 Location Map

Ontario has 8.6 million residents, 35 per cent of Canada's population. Approximately 7.8 million people live in southern Ontario, primarily around the southern Great Lakes.

Ontario has a total area of 1.06 million square kilometres (km^2), 11 per cent of the total area of Canada.

The province can be divided into three geographical regions, as shown on the map opposite. Most of Ontario is forest (58 per cent) and tundra (23 per cent). Farmland makes up 10 per cent of Ontario and the Great Lakes account for the remaining 9 per cent of the area. Urban areas account for less than 1 per cent of the area of Ontario.

Agricultural production for domestic and export use plays a key role in the overall economy of Ontario. A large complex of manufacturing industries ranging from primary steel production to sophisticated electronic component assembly is concentrated at the west end of Lake Ontario. In 1979, the manufacturing sector employed over 900 000 workers to meet the needs of complex domestic and international markets.

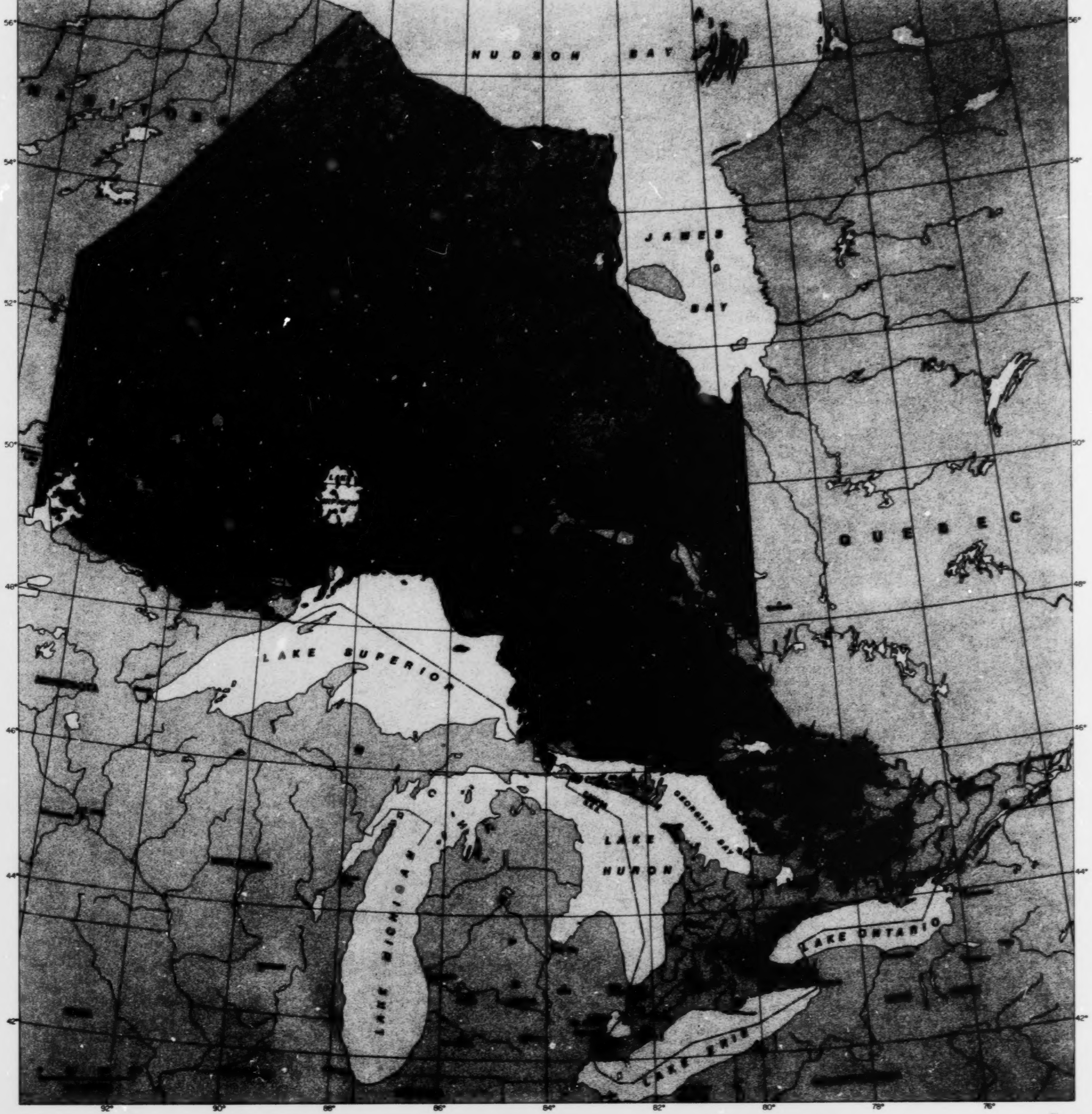
Ontario is also a producer of oil and natural gas, and a world leader in the production of gold, copper, nickel, uranium and other minerals.

Ontario produces 18 per cent of Canada's timber harvest. The large forested areas in central and northern Ontario also provide a significant natural resource for the production of lumber and all of the associated products for domestic use and export.

The extensive network of lakes and rivers in the province has allowed the development of large hydroelectric projects. It has also provided unlimited opportunity for a wide variety of water-related activities ranging from shipping and fishing to boating, cottaging and other water-related activities. With the tremendous variety of recreational opportunities in the province, tourism has become Ontario's largest industry.

Ontario's water resources are vital to maintaining and expanding the province's extensive agricultural, recreational, manufacturing, and resource development sectors in the years to come.

▨	TUNDRA	⌀	PRINCIPAL HYDROELECTRIC DEVELOPMENT
■	FORESTED AREA	⚒	PRINCIPAL MINING AREA
▨	AGRICULTURAL AREA	△	PRINCIPAL OIL FIELD
■	PRINCIPAL MANUFACTURING AREA	●	PRINCIPAL GAS FIELD
		▲	PRINCIPAL OIL AND GAS FIELDS


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE
56°
54°
52°
50°
48°
46°
44°
42°
92°
90°
88°
86°
84°
82°
80°
78°
76°

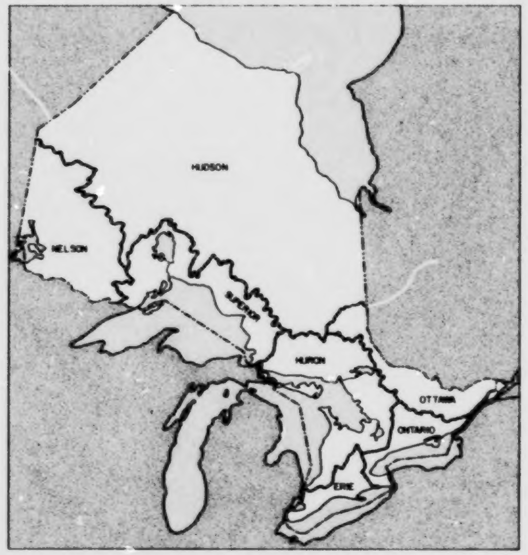
2 - Ontario's Water and Its Use

Ontario has abundant freshwater resources, and the ready availability of this water for many diverse uses has contributed, and continues to contribute, to Ontario's economic and social prosperity. These paragraphs summarize the overall balance between water availability and water use in the province. Surface water resources, ground water resources and water use in Ontario are discussed later in some detail within the context of the hydrologic cycle, as illustrated in the frontispiece.

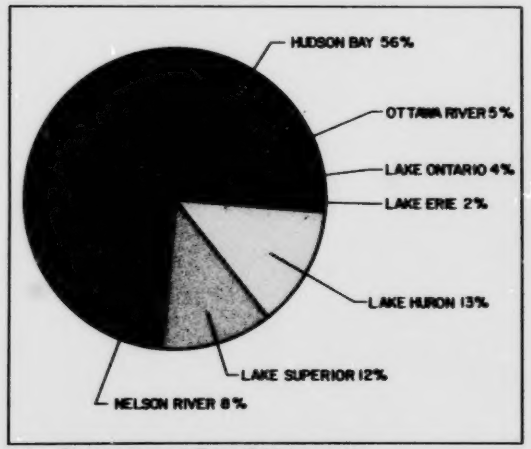
A simplified evaluation has been made of the balance between Ontario's water resources and water uses based on the major basin divisions shown in Figure 2.1. The Nelson, Ottawa and Hudson basins are considered as independent basins, while the Superior, Huron, Erie and Ontario basins are components of the larger Great Lakes drainage basin.

The basic water balance **for water from Ontario sources only (including the Great Lakes)** is illustrated on the flow chart opposite. The components of the water balance include

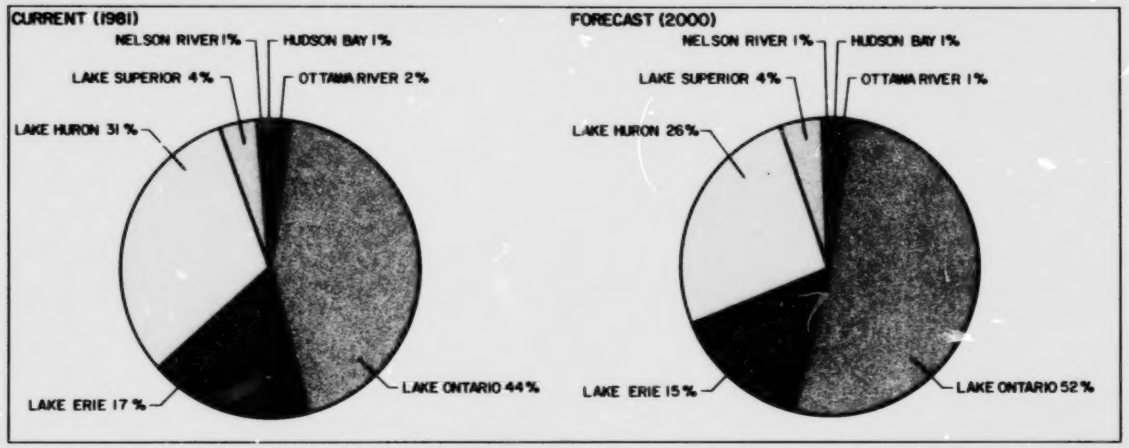
- runoff from surface and ground water within the drainage basin
- inflow to the drainage basin from the lake im-



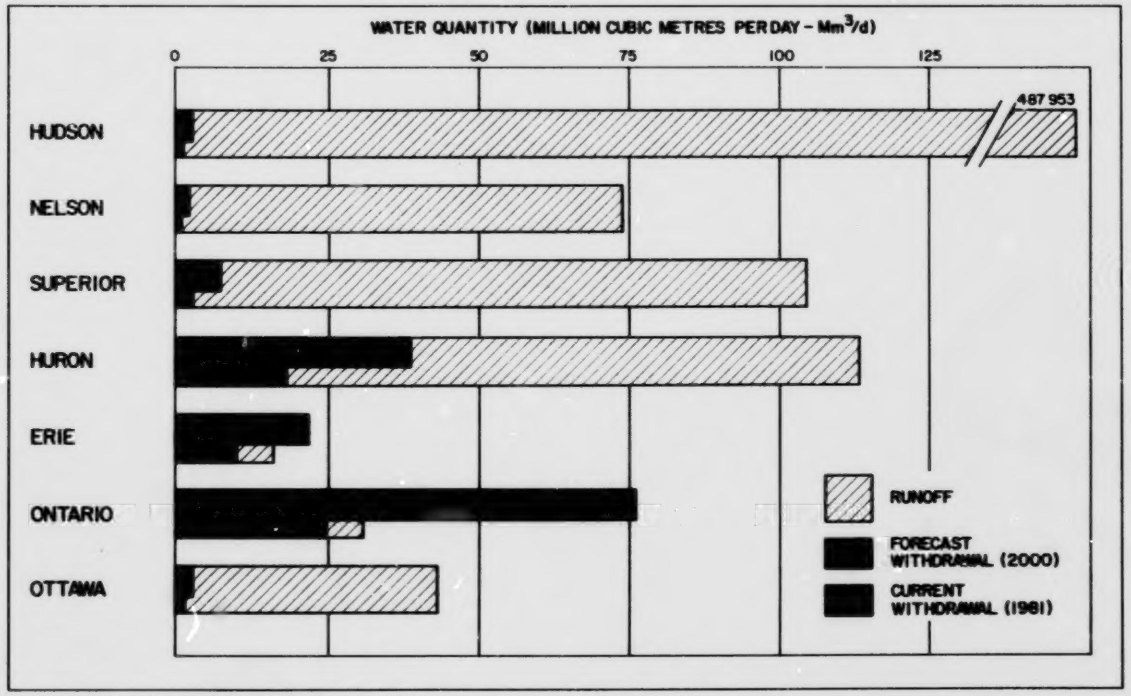
2.1 *Drainage Basins*



2.2 *Distribution of Runoff Volumes by Drainage Basin*



2.3 *Distribution of Water Withdrawals by Drainage Basin*



2.4 *Comparison of Water Withdrawals and Runoff* mediately upstream (within the Great Lakes basin)

- water withdrawn from water bodies within the basin
- the portion of withdrawn water that is consumed during use
- water that is returned after usage to water bodies within the basin.

Mean annual runoff is shown schematically to increase from zero at the upstream end of a drainage basin to its full amount, less consumption, at the downstream end. In the case of the Great Lakes, the outflow from a lake from Ontario sources is equal to the inflow from the previous lake, plus the basin runoff and minus the consumption. Lake inflow and basin runoff are drawn to the same scale to give a province-wide perspective. Current values (base year 1981) and estimated future values (forecast year 2000) are tabulated.

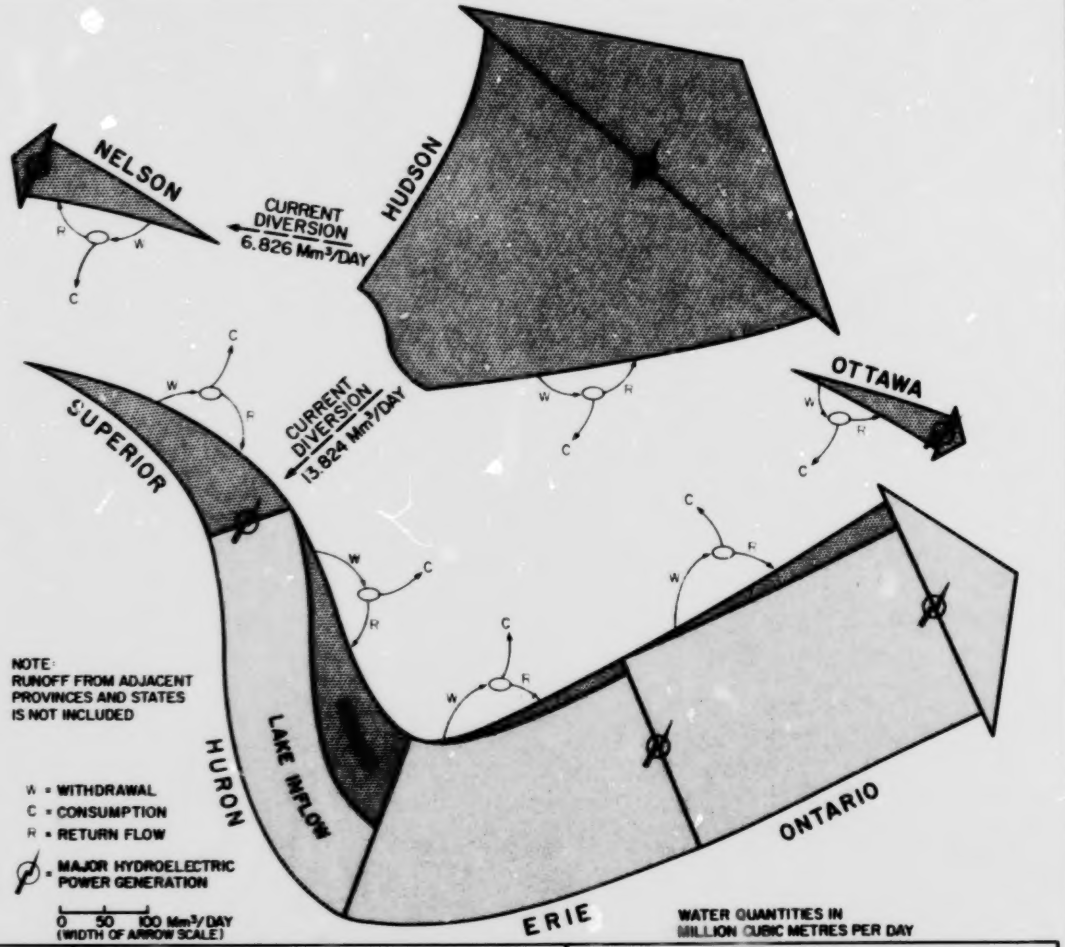
Water consumed during use is a very small component of the water balance. In the Ontario portion of the Great Lakes basin, the estimated consumption of water for the year 2000 is about 3.5 Mm³/d, which is only 1.3 per cent of the corresponding runoff. On the other hand, the corresponding total water withdrawals are very significant, the estimated value for the year 2000 being about 143.1 Mm³/d, representing 54 per cent of the available runoff.

Figures 2.2 and 2.3 indicate clearly the contrast between the substantial water resources in northern Ontario and the heavy water usage in southern Ontario. The Lake Ontario basin (including the lake surface) receives about 4 per cent of the province's mean annual runoff and currently accounts for 44 per cent of the province's water use.

Figure 2.4 shows that by the year 2000, water withdrawals in both the Lake Erie and Lake Ontario drainage basins are estimated to exceed the corresponding basin runoff, thus making water usage in these basins dependent on inflow from upstream lakes to maintain current quality criteria.

Water losses from individual drainage basins due to consumption are not generally significant as long as withdrawn water is returned to the same basin. However, in the case of transfer of water between basins, the water losses or gains become significant. Such diversions may be determined initially in terms of transferring surplus runoff from one basin to meet a high usage in another basin. However, although such surplus runoff may not be needed for withdrawal uses, there may be an inherent need for it within the basin where it occurs.

In Ontario, the greatest impact of flow changes caused by inter-basin diversions would be on hydroelectric power generating capabilities, principally at the locations shown on the diagram below. Hydroelectric power energy generation currently represents 34 per cent of Ontario's total and 10 per cent of Canada's total. In addition, if flow changes were to be accompanied by changes in water levels on the Great Lakes, navigation and Ontario's commercial shipping industry, which handles 21 per cent of the total waterborne cargo handled in Canada, would also be affected. Impacts on other interests such as water-oriented recreation, fishing and wildlife conservation might also occur.


NELSON
HUDSON
CURRENT DIVERSION 6.826 Mm³/DAY
CURRENT DIVERSION 13.824 Mm³/DAY
OTTAWA
SUPERIOR
LAKE INFLOW
HURON
ONTARIO
ERIE
W
C
R
NOTE: RUNOFF FROM ADJACENT PROVINCES AND STATES IS NOT INCLUDED
W = WITHDRAWAL
C = CONSUMPTION
R = RETURN FLOW
Ø = MAJOR HYDROELECTRIC POWER GENERATION
0 50 100 Mm³/DAY (WIDTH OF ARROW SCALE)

WATER QUANTITIES IN MILLION CUBIC METRES PER DAY

DRAINAGE BASIN	YEAR 1981					YEAR 2000				
	INFLOW FROM UPSTREAM LAKE	RUNOFF WITHIN BASIN	WITHDRAWAL WITHIN BASIN	RETURN FLOW WITHIN BASIN	CONSUMPTION WITHIN BASIN	INFLOW FROM UPSTREAM LAKE	RUNOFF WITHIN BASIN	WITHDRAWAL WITHIN BASIN	RETURN FLOW WITHIN BASIN	CONSUMPTION WITHIN BASIN
HUDSON	–	487.953	0.381	0.356	0.025	–	487.953	1.059	1.022	0.037
NELSON	–	73.673	0.410	0.385	0.025	–	73.673	1.137	1.101	0.036
SUPERIOR	–	104.953	2.466	2.349	0.117	–	104.953	6.849	6.678	0.171
HURON	104.836	113.426	17.675	17.216	0.459	104.782	113.426	37.962	37.033	0.929
ERIE	217.803	16.043	10.011	9.476	0.535	217.279	16.043	21.943	21.060	0.881
ONTARIO	233.311	30.803	25.093	24.249	0.844	232.441	30.803	76.340	74.823	1.517
OTTAWA	–	43.363	1.011	0.809	0.202	–	43.363	2.172	1.762	0.410
TOTAL	–	870.214	57.047	54.840	2.207	–	870.214	147.460	143.479	3.981

SURFACE WATER RESOURCES

Introduction

Ontario's extensive system of rivers drains the province primarily north to Hudson Bay and east through the Great Lakes system to the St. Lawrence River with a small part of western Ontario draining west to Manitoba. Pages 14 and 15 show this network of rivers and lakes and the heights of land which separate the various drainage basins. The lakes store water during high river flow and release it at a later time. This regulation of river flow affects the length of time that it takes for precipitation to become available as runoff. In southern Ontario, the Great Lakes system acts as a giant reservoir. At the outlet of Lake Erie, the spring flood flow is about 2.3 times the summer low flow, while on the Albany River in the north, the ratio is almost 90 times the summer low flow.

The discussion which follows has been broken down into a number of discrete topics. However, these topics can be generally grouped into 2 broad areas

- precipitation and related climatic factors
- surface runoff and stream/river flows.

Precipitation in the form of rainfall and snowfall provides surface water resources. Information on precipitation and how it is affected by weather conditions, topography and other natural conditions throughout the province is presented and discussed on pages 16 through 23.

About 57 per cent of Ontario's precipitation does not run off into rivers and lakes since it returns to the atmosphere through the combined effects of direct evaporation and transpiration by vegetation and forests.

The distribution of runoff throughout the province and the way in which river flows vary during different seasons are described on pages 24 to 33. Runoff is a measure of the amount of precipitation that is available for use.

In Ontario, about 43 per cent of the total annual precipitation appears as surface runoff. While the runoff from rain or melted snow is very limited in the winter, extensive lake storage ensures that many rivers carry a substantial year-round flow. This year-round flow is important to municipalities which rely on rivers for water supply and to hydroelectric generation facilities.

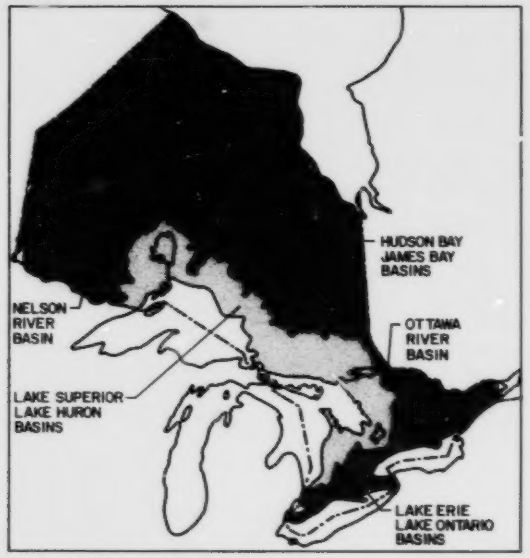
The various references used in compiling the surface water data are listed on page 34.

3 – Drainage Basins

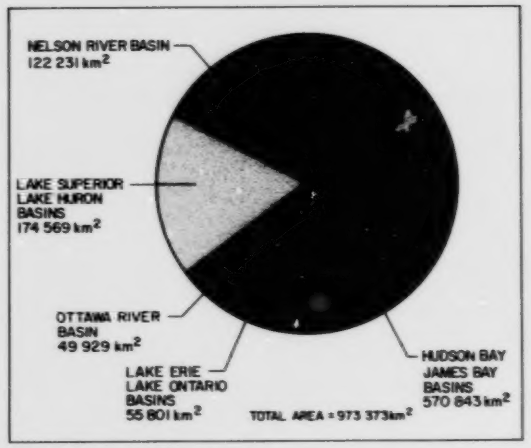
Drainage basins determine both the amount and direction of movement that surface water takes. Within the basin area, the arrangement of lakes and streams determines how the surface water will be stored and released over a period of time.

The map opposite shows the major rivers and lakes in the province, together with the boundaries of the primary and secondary drainage basins. The limits of these basins in adjacent provinces and states are also shown.

Five major provincial drainage basins are highlighted in Figure 3.1. Figure 3.2, which excludes the Great Lakes, shows that 71 per cent of the province drains to Hudson Bay directly or via Manitoba. The remaining 29 per cent of the province drains to the Great Lakes/St. Lawrence system.



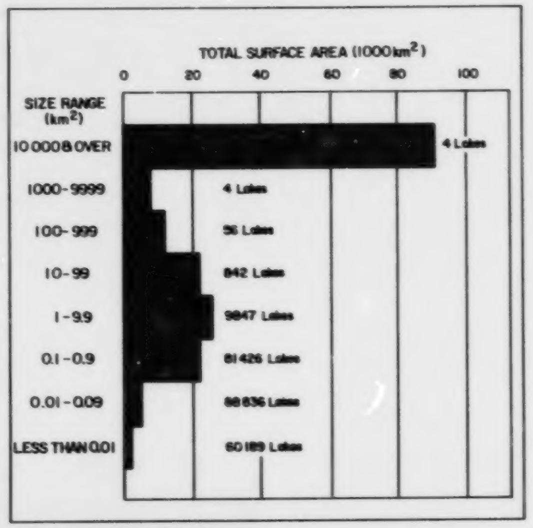
3.1 *Five Major Drainage Basins*



3.2 *Areas of Major Basins*

In some areas the topography near the basin boundaries permits diversion of water from one basin to another with a moderate investment in channels and control structures. This has happened along the divide between the Great Lakes basin and the Hudson Bay basin, as shown on the map opposite where 19 170 km^2 (7400 mi.^{2}) or 3.4 per cent of the area of the Hudson Bay/James Bay basins has been redirected to flow south in two diversions. The most important benefit of these diversions is the increase in hydroelectric generation which the additional flow provides between Lake Nipigon and Lake Superior, at Sault Ste. Marie, and at the Niagara and St. Lawrence River plants. In addition, 12 300 km^2 (4750 mi.^{2}) or 2 per cent of the Hudson Bay/James Bay basins is directed to the Nelson River basin and ultimately to Hudson Bay. This diversion provides water for water level control purposes on Lake of the Woods and related hydroelectric power production.

A recent study identified 226 918 lakes in Ontario. These lakes, including the Great Lakes, have a total surface area of 181 153 km^2 (69 944 mi^2), which is about 17 per cent of the total area of the province. For comparison purposes, freshwater covers 8 per cent of the total area of Canada and 2 per cent of the area of Alberta. There are estimated to be over one million lakes or ponds larger than 0.01 km^2 (2.5 acres). Most of these lakes are between 0.01 and 0.1 km^2 in area and cannot be identified at the mapping scale which is currently available, particularly in northern areas. Figure 3.3 shows that 95 per cent of the lakes and ponds have a surface area of less than 1 km^2 (247 acres).



3.3 *Lake Size Distribution*

In the Hudson Bay/James Bay basins, lakes cover about 8 per cent of the total drainage area and in the Nelson River basin, the comparable figure is 18 per cent. In the Great Lakes/Ottawa River basins, the Great Lakes represent 24 per cent and other inland lakes represent 6 per cent of the total drainage area. A high percentage of lake area in a basin causes flows to be more evenly distributed throughout the year.

Data Collection for Water Resource Management

Because of the continuous variation of flow throughout the year and from one year to the next, comprehensive information about river flows and lake levels requires data collection over a long period of time, usually on a continuous basis.

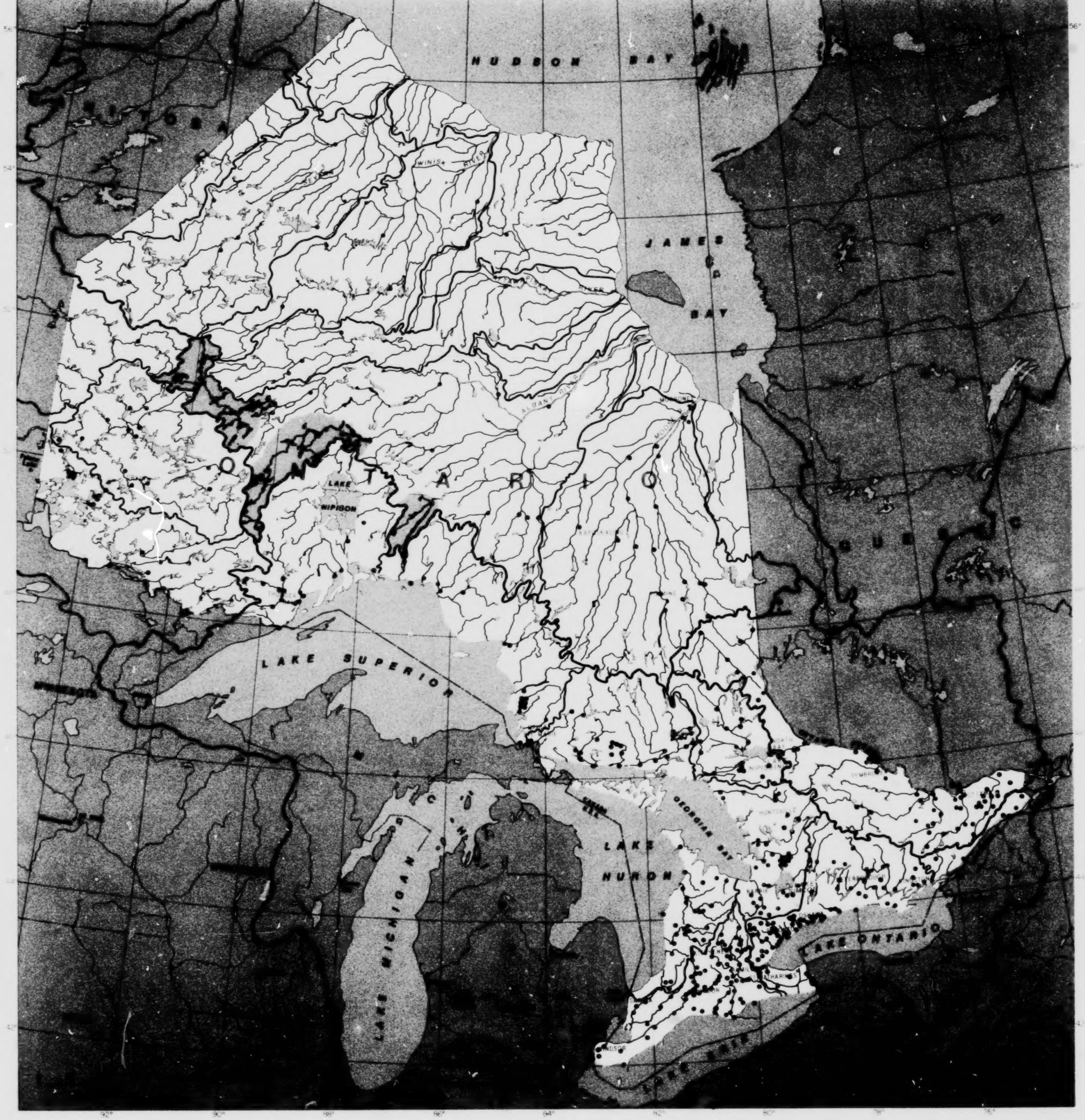
Flow records are accumulated using approximately 500 streamflow gauges distributed on rivers throughout the province, as shown on the map opposite. About 40 per cent of these gauges have been operating for more than 20 years. One hundred and fifty of these gauges are equipped to be read remotely for flood prediction or monitoring.

The number of streamflow gauges with long records in southern Ontario has made it possible to develop a fairly good understanding of surface water resources. In the north, this is not the case. The lack of long continuous periods of record at these remote locations results in an incomplete understanding of northern water resources.

References listed on page 34:

- 3.1 and 3.2

STREAMFLOW GAUGES
YEARS OF RECORD
SEASONAL
● 0-9
● 10-19
● 20-29
● 30 AND OVER
▨ MAJOR DIVERSION AREA
— PRIMARY DRAINAGE BASIN BOUNDARY
~ SECONDARY DRAINAGE BASIN BOUNDARY



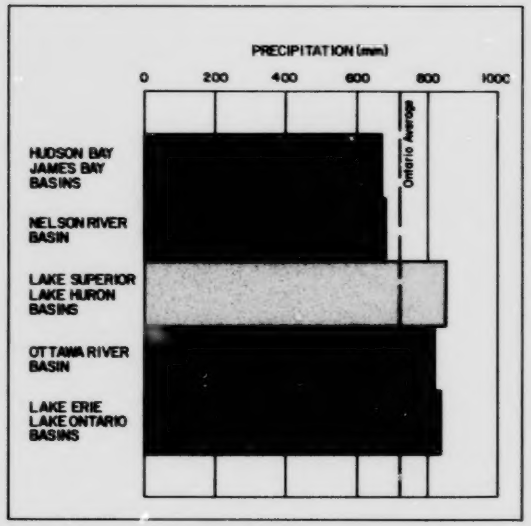
HUDSON BAY
JAMES BAY
MANITOBA
ONTARIO
QUEBEC
LAKE NIPIGON
LAKE SUPERIOR
MICHIGAN
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE
MINNESOTA
WINISK RIVER
ALBANY RIVER
92°
90°
88°
86°
84°
82°
80°
78°
76°
56°

4 – Mean Annual Precipitation

Precipitation includes all forms of snowfall and rain which reach the earth's surface.

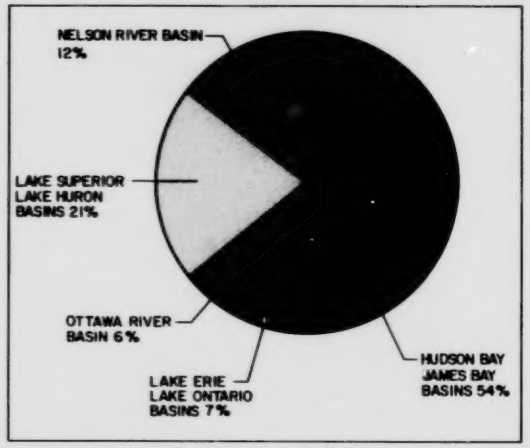
Ontario's mean annual precipitation is 724 mm (28.5 in.) and is distributed across the province in a reasonably uniform pattern. Localized zones of higher precipitation are associated with the Great Lakes. The amount varies from 500 mm in the northwest corner of the province to 1,000 mm to the east of Lakes Superior and Huron. Figure 4.1 shows the amount of precipitation in each of 5 major basins. Comparative annual precipitation figures for other parts of Canada are shown below

- British Columbia coast	- 1,600 to 3,200 mm
- Alberta and Saskatchewan prairies	- 400 to 500 mm
- Maritime provinces	- 1,200 to 1,600 mm.



4.1 Mean Annual Precipitation

This mean annual precipitation depth of 724 mm corresponds to a volume of 705 cubic kilometres (km³), or about 1.5 times the volume of water in Lake Erie. Figure 4.2 shows that, although average precipitation is less in the north, approximately two thirds of the total precipitation volume in Ontario falls on the Hudson Bay/James Bay and Nelson River drainage basins, and does not drain through the populated southern portion of the province.



4.2 Distribution of Precipitation Volume

Measurement of Precipitation

The physical process of lifting moist air masses and cooling them condenses the water vapour which they contain and results in precipitation. The moisture in the air may be carried long distances from tropical areas or may be generated by evaporation close to the zone of precipitation as occurs on the Great Lakes during the fall and winter.

Precipitation, which includes rain and the water equivalent contained in snowfall, is measured in millimetres using gauges located throughout the province, as shown on the map opposite. The precipitation information from these gauges is compiled into maps summarizing the long-term mean annual precipitation. This information has been developed from data collected during the 30-yr period from 1941 to 1970 and is reproduced directly from the Hydrological Atlas of Canada.

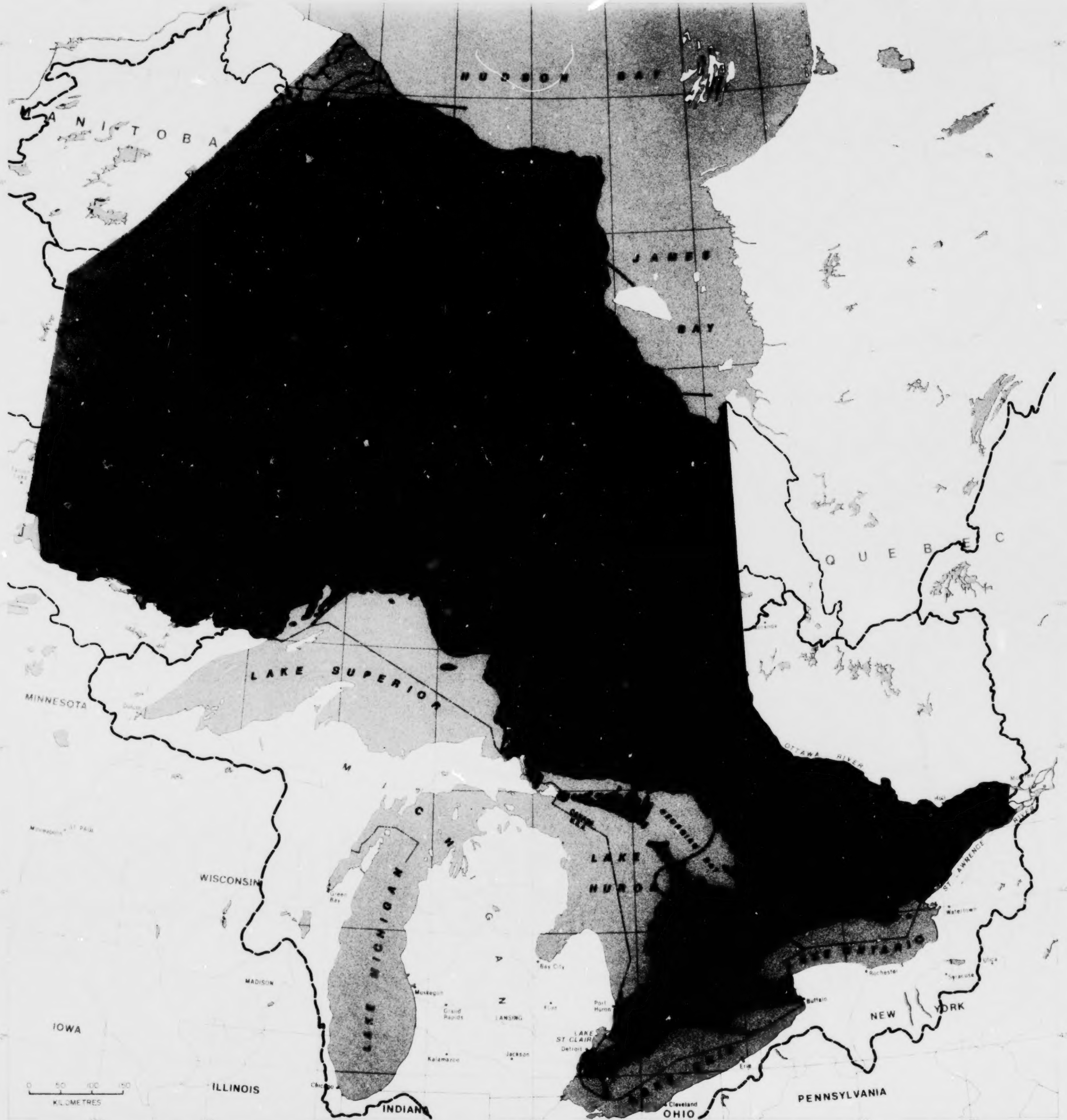
Reference listed on page 34:

- 4.1

MEAN ANNUAL PRECIPITATION
(mm)

▨ 500
▨ 600
▨ 700
▨ 800
▨ 900
▨ 1000

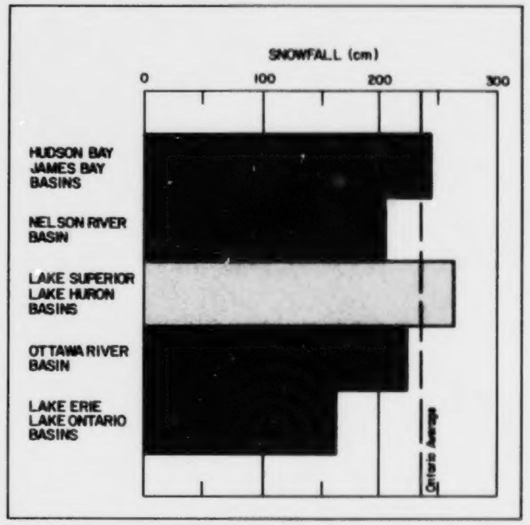
● CLIMATOLOGICAL STATION
— PRIMARY DRAINAGE BASIN BOUNDARY
— SECONDARY DRAINAGE BASIN BOUNDARY


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
OTTAWA RIVER
ST. LAWRENCE RIVER
LAKE SUPERIOR
MINNESOTA
Duluth
Minneapolis
ST. PAUL
MICHIGAN
WISCONSIN
Green Bay
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
NORTH CHANNEL
MADISON
Muskegon
Grand Rapids
LANSING
Bay City
Flint
Port Huron
LAKE ST CLAIR
Detroit
Kalamazoo
Jackson
IOWA
ILLINOIS
Chicago
INDIANA
OHIO
Cleveland
LAKE ERIE
Erie
Buffalo
LAKE ONTARIO
Rochester
Syracuse
Utica
Watertown
Montreal
NEW YORK
PENNSYLVANIA
0 50 100 150
KILOMETRES
92°
90°
88°
86°
84°
82°
80°
78°
76°

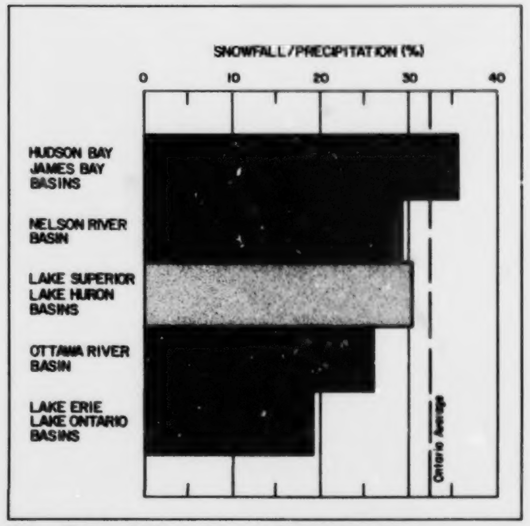
5 – Mean Annual Snowfall

Snowfall is generally defined as precipitation which falls as snowflakes, snow pellets, snow grains, ice pellets, hoarfrost and minute ice crystals. Hail and freezing rain are excluded.

Ontario's mean annual snowfall is 235 cm (92.5 in.). Generally in the colder northern part of the province the longer winter usually results in a greater total snowfall. However, local areas of large snowfall exist to the east of Lakes Superior and Huron where the open lakes supply moisture to the subzero winter air. Figure 5.1 illustrates the mean annual snowfall for 5 major drainage basins.



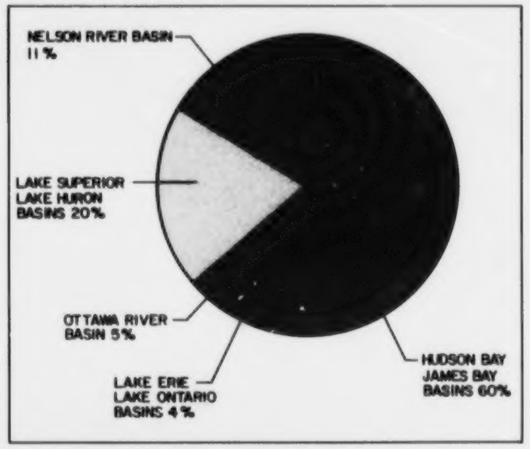
5.1 *Mean Annual Snowfall*



5.2 *Ratio of Mean Annual Snowfall to Mean Annual Precipitation*

Assuming a relative snow/water density of 0.1, 32.5 per cent of the total precipitation in the province falls as snow. Thus, a large portion of the precipitation does not run off immediately but, rather, is delayed until snowmelt occurs in the late winter or early spring. The high proportion of snowfall shown in Figure 5.2 for the northern basins is one reason for the relatively high spring runoff which occurs. The rate at which the runoff occurs in the spring is also influenced by the lake storage available in each basin, as discussed on page 14.

The equivalent water depth of 235 mm for the mean annual snowfall across the province corresponds to a volume of 227 km^3, or about 50 per cent of the volume of Lake Erie. Seventy-one per cent of this water volume falls on the Hudson Bay/James Bay and Nelson River drainage basins as shown in Figure 5.3.



5.3 *Distribution of Snowfall Volume*

The storage of a significant percentage of precipitation as snowfall and its very sudden release has very important impacts on water management. In these areas, any efforts to use the runoff must take into account the storage factor during the winter months and the very quick release of the stored precipitation during a relatively short period in the spring.

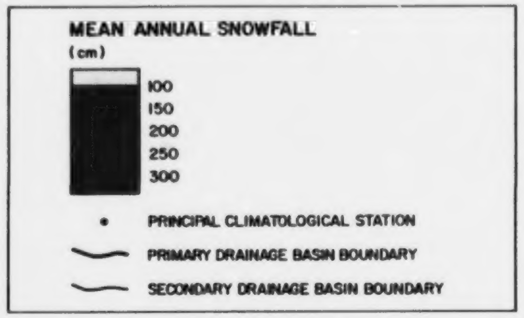
Measurement of Snowfall

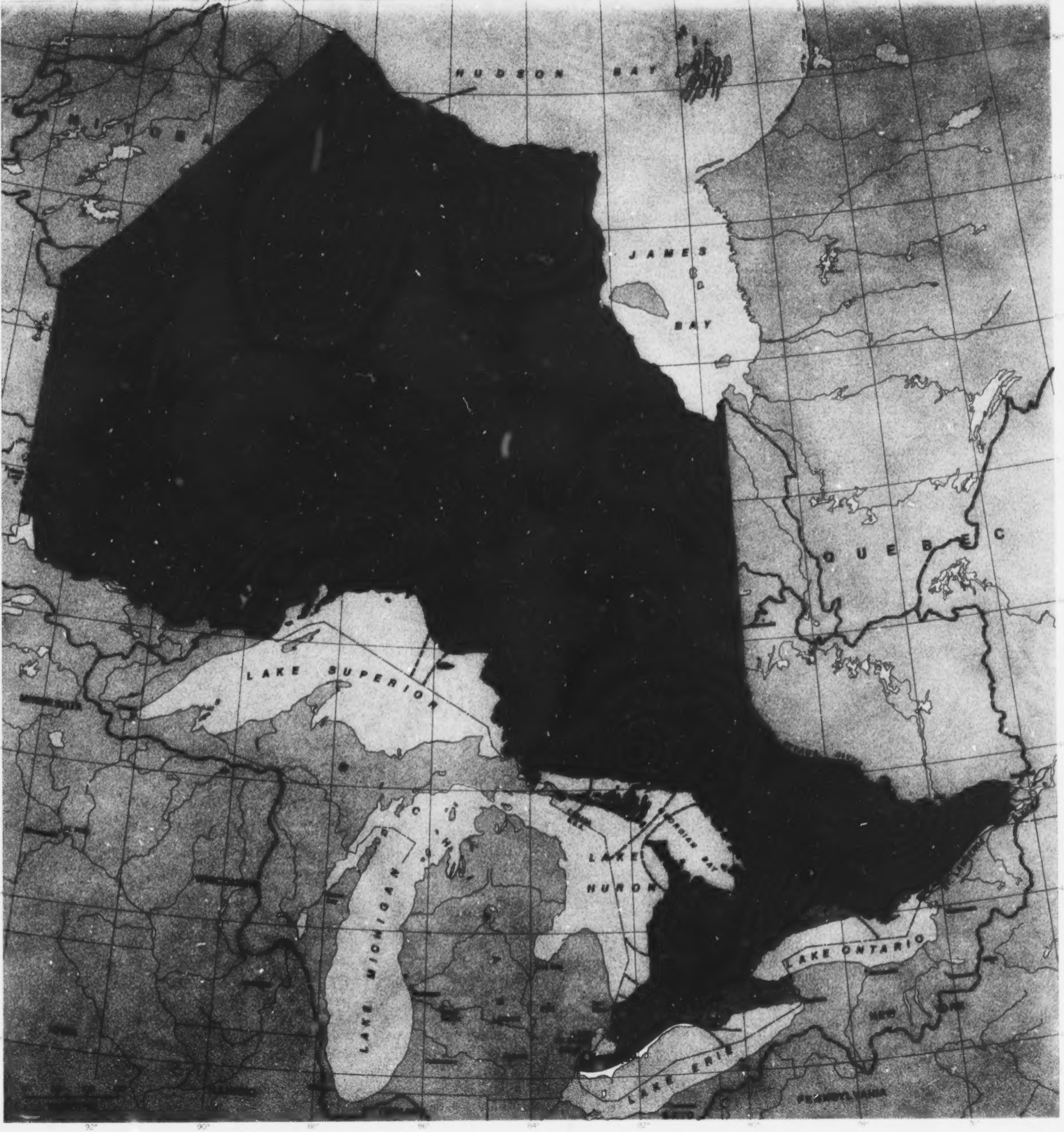
Snowfall depths are measured regularly at climatological stations. Normally the water equivalent of snowfall is estimated assuming a relative snow/water density of 0.1, i.e., 1 cm of snow is equivalent to 1 mm of water (10 in. of snow is equivalent to 1 in. of water). This is a valid approximation for most applications. However, the actual relative density of snowfall varies from 0.05 to 0.15, depending on storm conditions and site location. Therefore, at principal stations where total precipitation is required, direct measurement of rain and melted snow is used. Separation of total precipitation into rainfall and snowfall is desirable when determining the availability of water.

The isolines for 100 cm, 200 cm, etc, of mean annual snowfall shown on the map opposite were taken directly from Environment Canada mapping and the 150-cm, 250-cm, etc, isolines were estimated using Environment Canada data. These isolines are based on data collected during the standard 30-yr period from 1951 to 1980 from the principal climatological stations shown on the map. It should be noted that the isolines represent total annual snowfall, i.e., the sum of the depths of snow from each fall, not snow on the ground at the end of the winter.

References listed on page 34:

- 5.1 to 5.4 inclusive

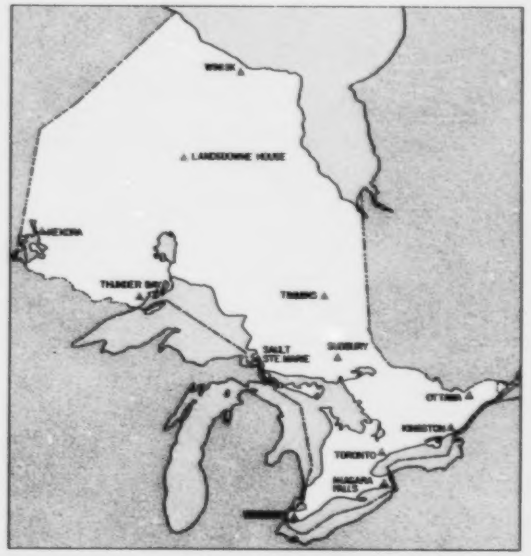

MEAN ANNUAL SNOWFALL
(cm)
100
150
200
250
300
PRINCIPAL CLIMATOLOGICAL STATION
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
NEW YORK
PENNSYLVANIA
56°
54°
44°
92°
90°
88°
86°
84°
82°
80°

6 – Monthly Distribution of Precipitation

Mean annual precipitation and snowfall maps provide a good overall picture of magnitudes. However, in order to evaluate the availability of surface water resources properly, it is necessary to know when and where rain and snow occur throughout the year.

To illustrate the distribution of precipitation on a monthly basis, several climatological stations, as shown in Figure 6.1, were selected across the province. Bar graphs showing the rain and snow content of the precipitation on a monthly basis are shown on the page opposite for each of these stations. These bar graphs are based on data collected during the standard 30-yr period from 1951 to 1980, as tabulated by the Atmospheric Environment Service.

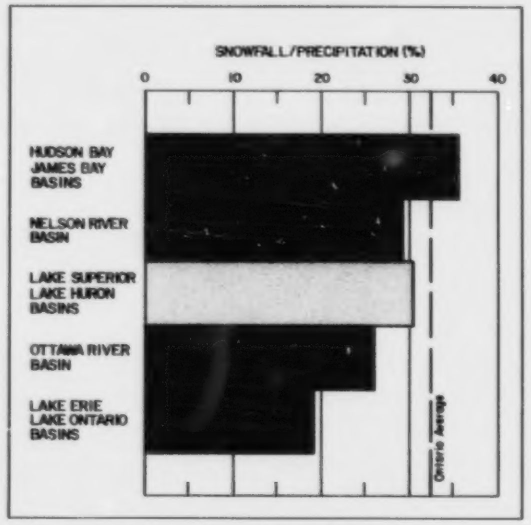


6.1 *Locations of Selected Climatological Stations*

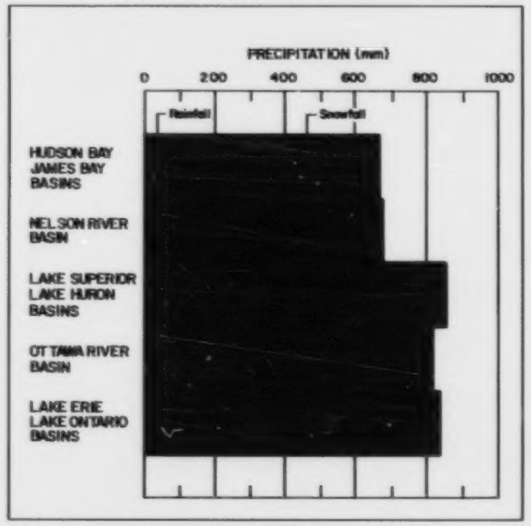
The total precipitation in Ontario is relatively uniform throughout all months except for the northern part of the province which drains to Hudson Bay/James Bay and the Nelson River. These northern drainage basins receive most of their precipitation during the summer and early fall periods.

Figure 6.2, repeated from page 18 for comparison purposes, shows that the relative amount of snowfall increases from 20 per cent for the Lake Erie/Lake Ontario basins to 36 per cent for the Hudson Bay/James Bay basins.

Figure 6.3 shows the mean annual precipitation in millimetres divided into rain and snowfall water content for each of 5 major basins.



6.2 *Ratio of Mean Annual Snowfall to Mean Annual Precipitation*

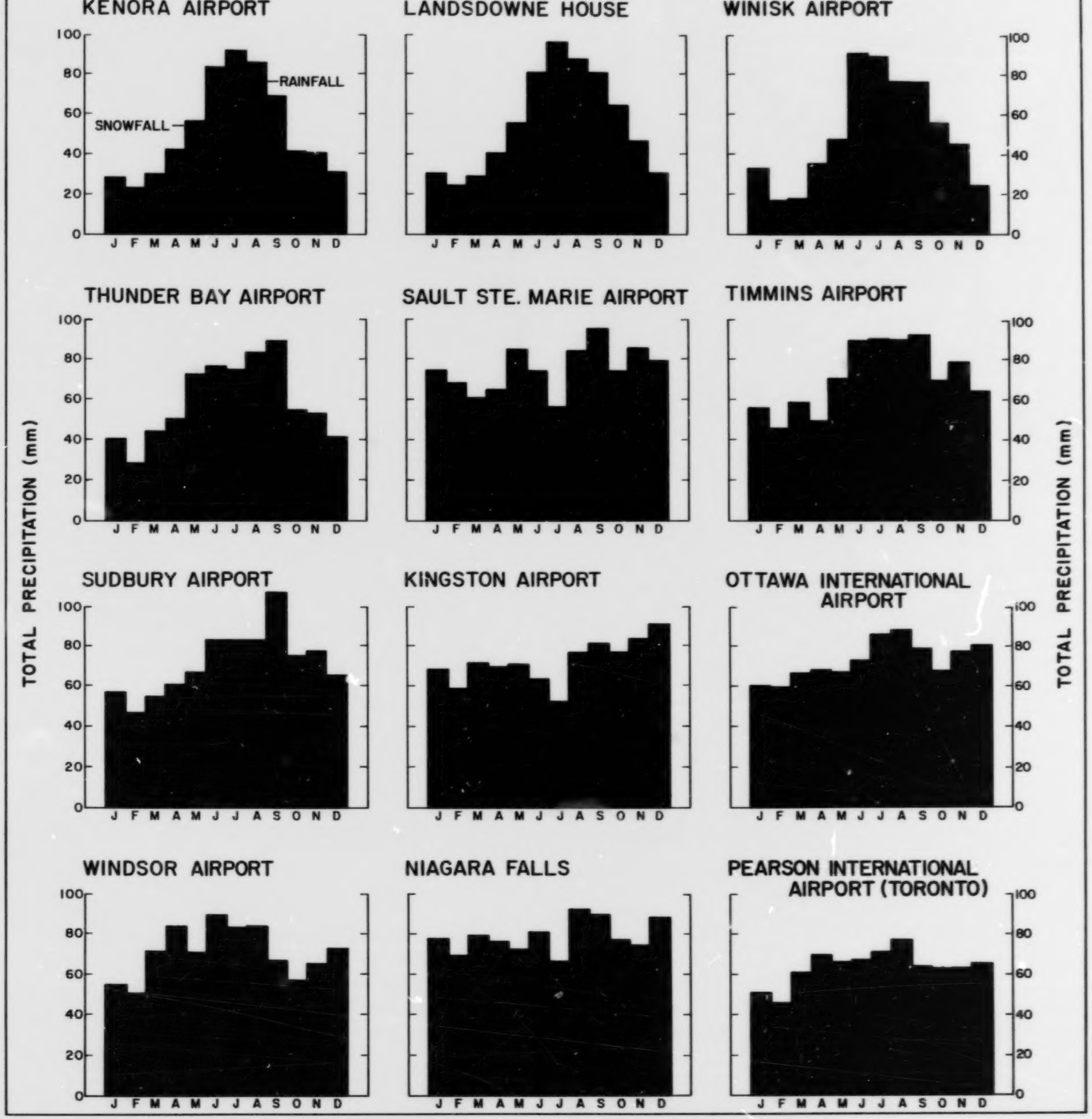


6.3 *Mean Annual Rainfall and Snowfall*

In drainage basins where snowfall forms a large proportion of the total annual precipitation, storage capacity is required to be able to utilize the runoff once the snow has melted. In southern Ontario where precipitation is uniformly distributed throughout the year and occurs primarily as rain, greater immediate utilization can be made of the runoff.

Reference listed on page 34:

- 6.1


KENORA AIRPORT
LANDSDOWNE HOUSE
WINISK AIRPORT
RAINFALL
SNOWFALL
THUNDER BAY AIRPORT
SAULT STE. MARIE AIRPORT
TIMMINS AIRPORT
SUDBURY AIRPORT
KINGSTON AIRPORT
OTTAWA INTERNATIONAL AIRPORT
WINDSOR AIRPORT
NIAGARA FALLS
PEARSON INTERNATIONAL AIRPORT (TORONTO)
TOTAL PRECIPITATION (mm)
TOTAL PRECIPITATION (mm)
0
20
40
60
80
100
J F M A M J J A S O N D

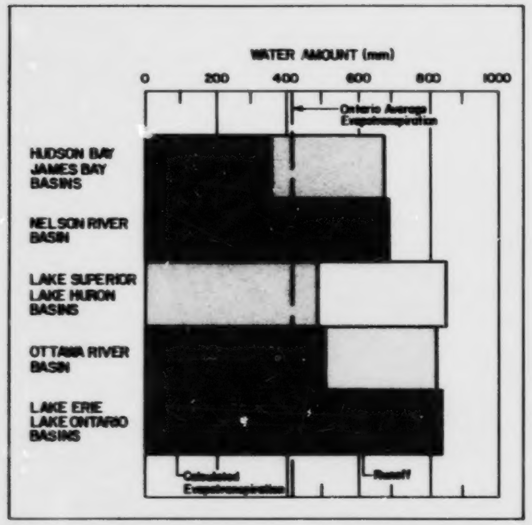
7 – Mean Annual Lake Evaporation and Evapotranspiration

Evaporation and evapotranspiration are, respectively, the movement of water from lake surfaces and the ground to the atmosphere and the total movement of water to the atmosphere by evaporation and transpiration from plants. Evapotranspiration is of greater importance to water resource management as it represents the total removal of water to the atmosphere by all processes. Any water removed in this way is not available for runoff, storage and eventual use.

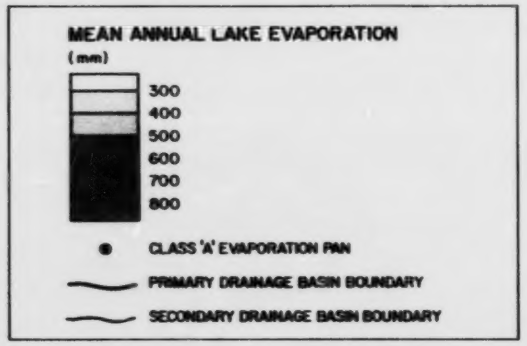
The isolines of mean annual lake evaporation were taken directly from the Hydrological Atlas of Canada. These isolines give the estimated evaporation rate which would be expected from the surface of a lake in a given area, excluding the Great Lakes.

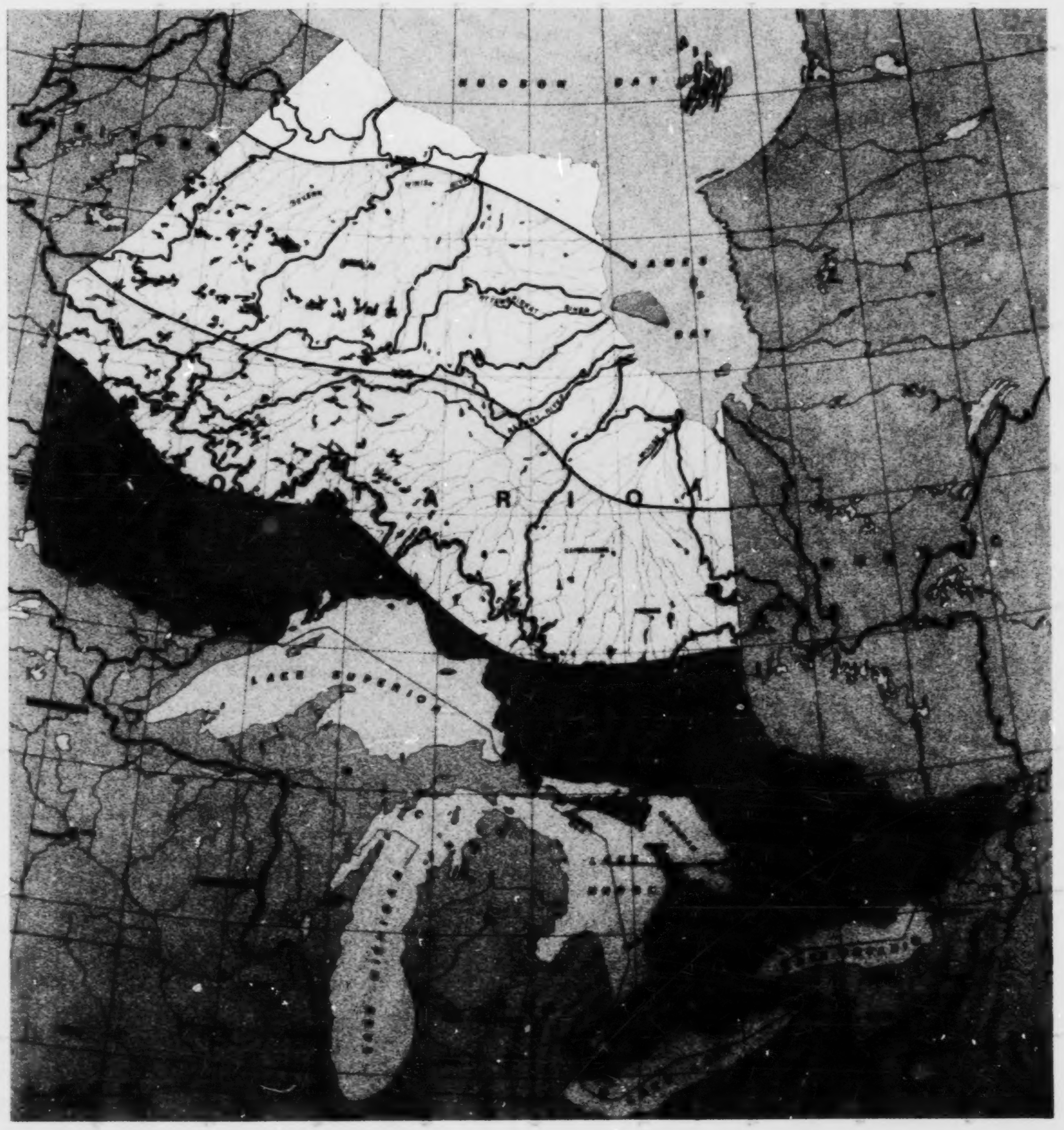
The mean annual evapotranspiration averaged over the province is 415 mm (16.3 in.) or 57 per cent of the total precipitation and varies from less than 300 mm in the north to over 600 mm in the south. Figure 7.1 shows that evapotranspiration is 65 per cent of the total precipitation in the Lake Erie and Lake Ontario basins, and declines to about 53 per cent for the Hudson Bay/James Bay basins. Two out of every 3 cubic metres of water that falls as precipitation on southern Ontario are, therefore, not available for use. Much of this loss to the atmosphere is actually due to water use in growing forests and agricultural crops. On the west and east coasts of Canada, the mean annual evapotranspiration is 400 to 500 mm, and on the prairies about 400 mm.

Evaporation directly from the Great Lakes is not represented by the isolines on either of the maps. Because of the massive volume of these lakes, they respond to seasonal temperature changes much more slowly than small lakes. This, and the very large areas involved, alters the seasonal distribu-



7.1 *Mean Annual Evapotranspiration and Runoff*

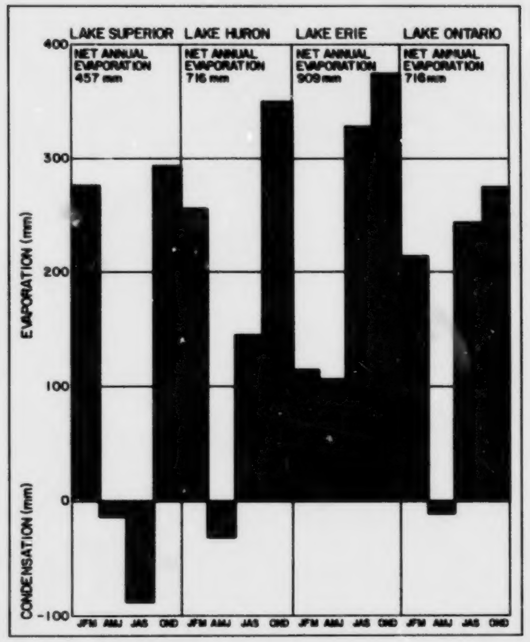

MEAN ANNUAL LAKE EVAPORATION
(mm)
300
400
500
600
700
800
CLASS 'A' EVAPORATION PAN
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY



tion of evaporation, particularly for those lakes which do not freeze over completely during the winter. Figure 7.2 shows that evaporation is least in the spring when the lakes are colder than the air, and greatest in the fall and early winter when the lakes are relatively warm. Lake Erie, the warmest lake, has a mean annual evaporation rate of 909 mm, which is approximately the same as the mean annual precipitation. Lake Superior, the coldest lake, has a net mean annual evaporation rate of 457 mm, which is about one-half the rate for Lake Erie. The amount of evaporation from the lower Great Lakes is a significant loss of water from the lake basins.

Determination of Lake Evaporation and Evapotranspiration

The isolines of mean annual lake evaporation were developed using pan evaporation data, as well as evaporation calculated from climatological data, including air temperature, wind velocity, relative humidity, and amount of possible bright sunshine. The stations that currently measure pan evaporation are shown on the map.

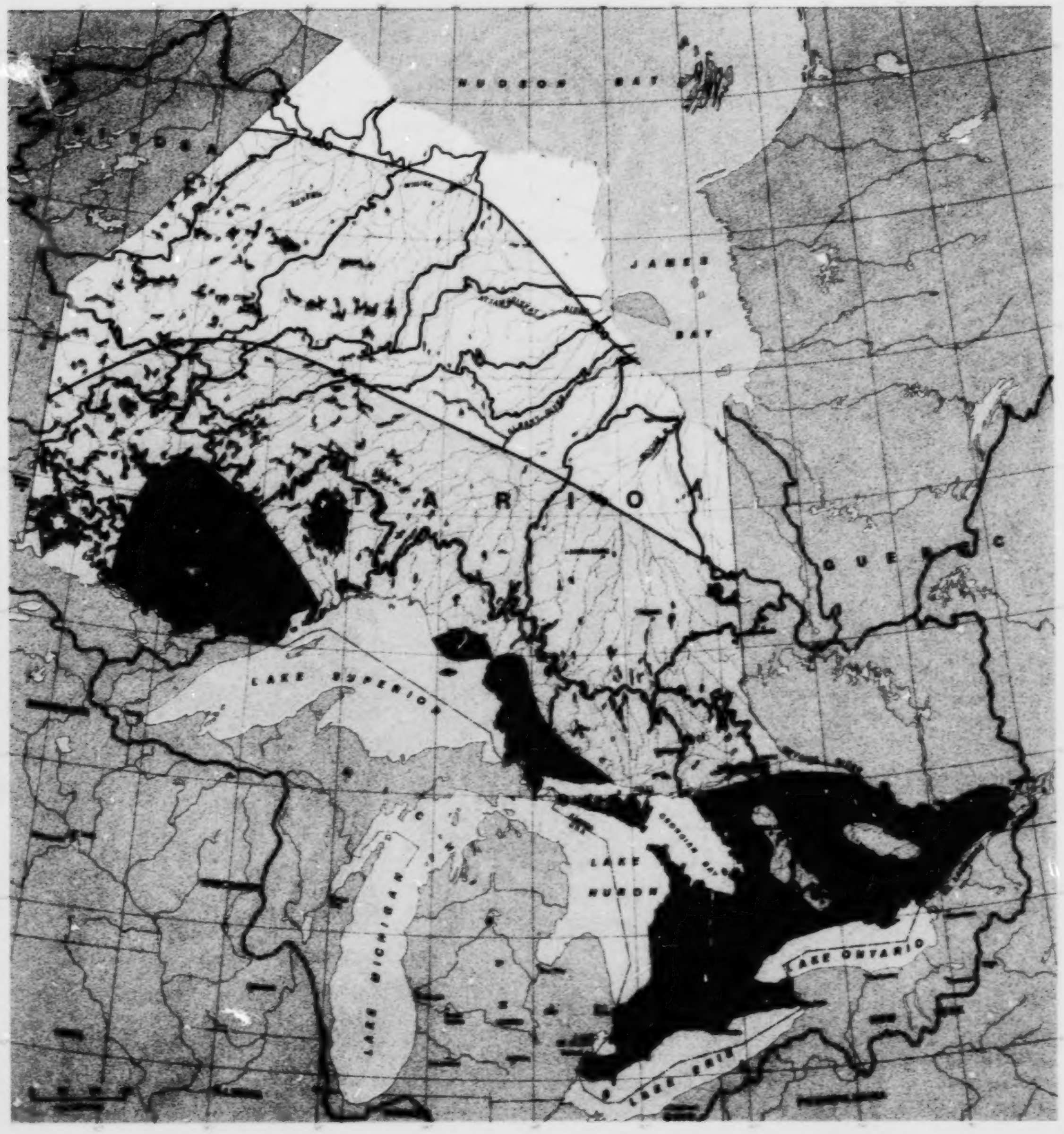


7.2 *Great Lakes Evaporation*

The isolines of mean annual evapotranspiration were calculated by subtracting mean annual runoff (map on page 27) from mean annual precipitation (map on page 17). Over a period of many years, average evapotranspiration is the difference between precipitation and runoff.

References listed on page 34:

- 7.1 to 7.3 inclusive


HUDSON BAY
JAMES BAY
ONTARIO
QUEBEC
LAKE SUPERIOR
LAKE HURON
GEORGIAN BAY
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
MEAN ANNUAL EVAPOTRANSPIRATION
(mm)
300
400
500
600
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY

8 – Freeze-up and Breakup of Lakes and Rivers

The 4 maps on the opposite page show the average dates when lakes and rivers become completely ice covered in the early winter and when the ice surface first deteriorates in the spring. These isolines of freeze-up and breakup dates were taken directly from maps published by the Atmospheric Environment Service. The dates are very approximate and can vary locally due to water body size, orientation and flow. Inland lakes generally freeze over completely while rivers may only become partially ice covered depending on water velocities. The Great Lakes are not included on these maps because their behaviour is different from the relatively small inland lakes and rivers. Ice conditions on the Great Lakes are discussed later.

Breakup dates are important since they indicate when water loss from ice and snow surfaces due to sublimation changes to water loss from open water surfaces due to direct evaporation. The rate of evaporation is generally higher than the rate of sublimation. Freeze-up and breakup dates are important to tourism since they determine the beginning and ending of water- and ice-based recreational activities.

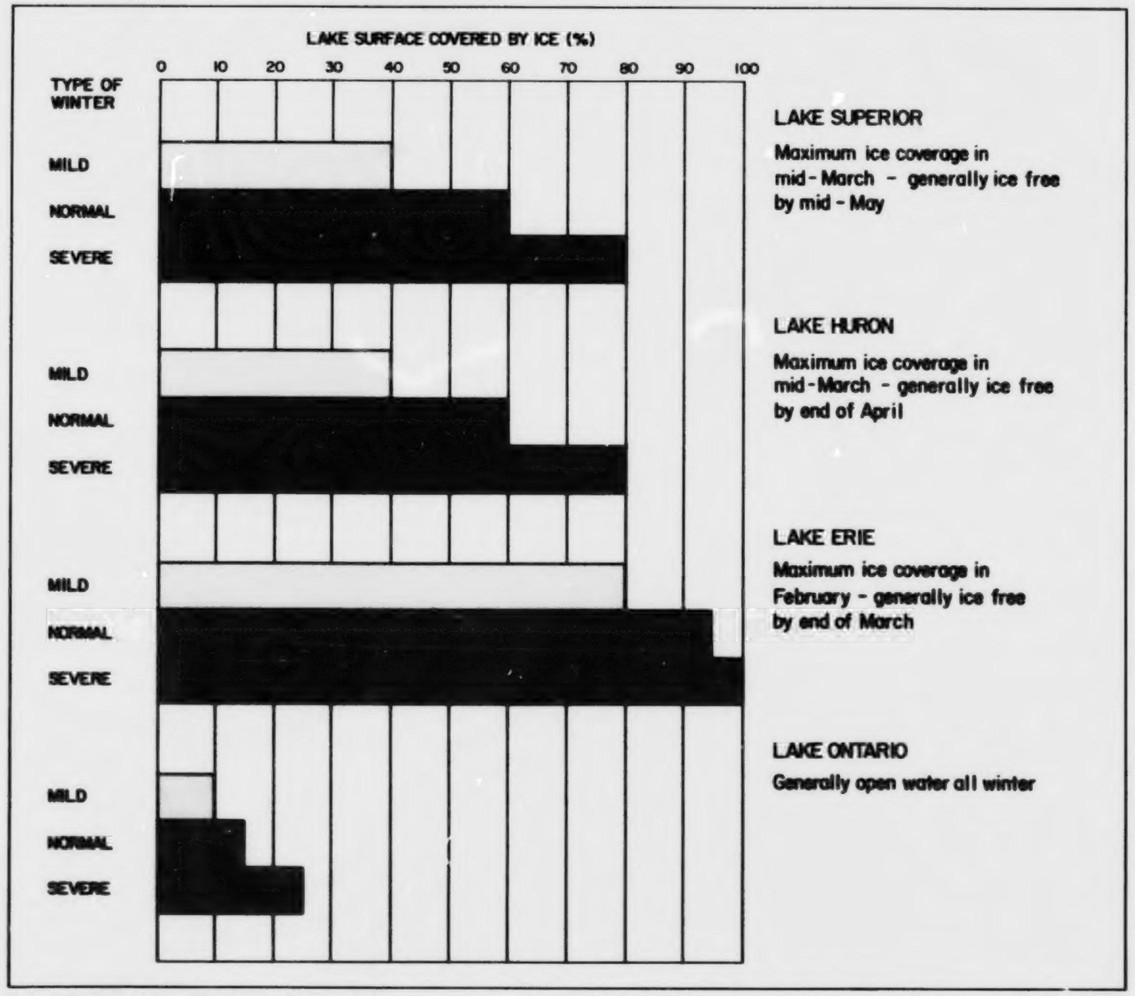
The period during which an ice surface is considered safe for traffic is generally 5 to 6 weeks shorter than the time between freeze-up and breakup. Local conditions can cause a significant variation in the safe ice period. Ice surface traffic in Ontario is mainly recreation oriented--ice fishing, snowmobiling, skiing, ice boating and, occasionally, skating. Transport of goods over ice surfaces is limited to a small number of locations in the northern regions. These winter roads (about 800 km) are funded by both the federal and provincial governments. They are normally open for a 2-month period during January and February.

The Great Lakes freeze to varying extents each year. Estimates of ice cover are developed from regular flights over the lakes during the ice cover period. Figure 8.1 summarizes the extent of ice cover according to the type of winter.

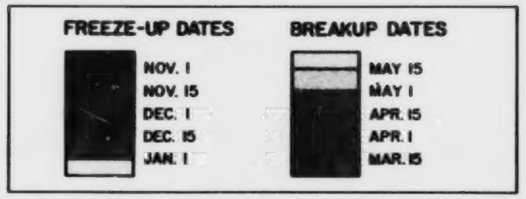
Ice conditions on the Great Lakes are very important to commercial shipping since navigation is limited to about 8.5 months each year. The Welland Canal, connecting Lakes Erie and Ontario, is generally open for navigation from April to mid-December, the main limitation being ice conditions on Lake Erie. The navigation season for the Sault Ste. Marie Canal is slightly shorter. Severe winter conditions can limit the total tonnage carried annually.

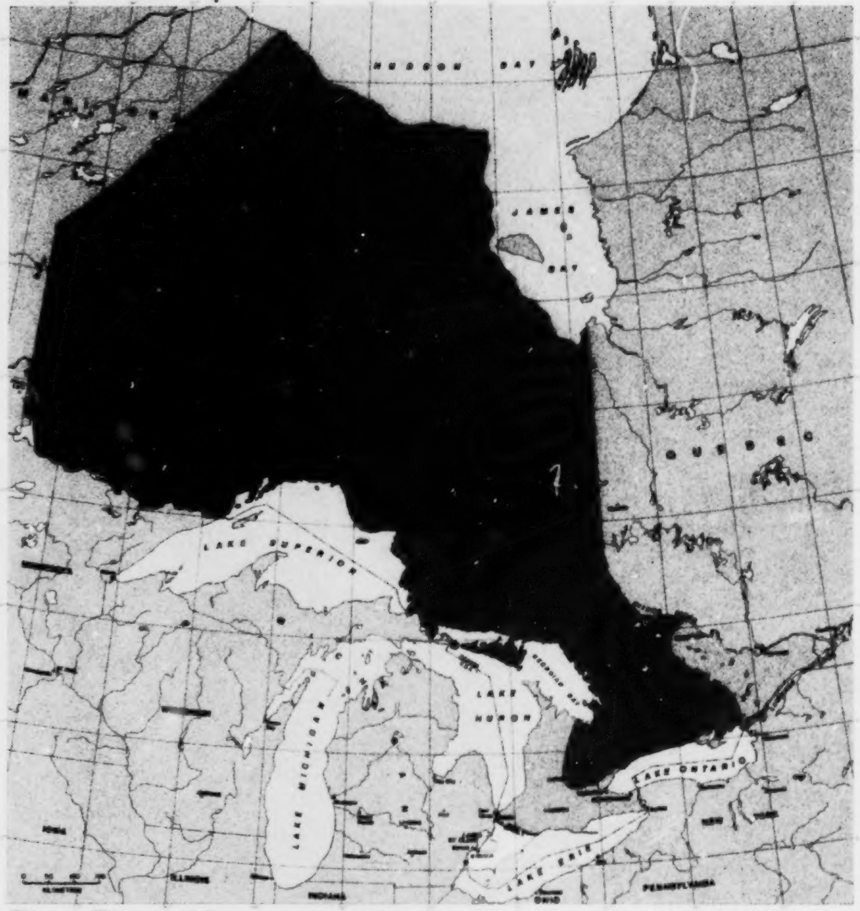
References listed on page 34:

- 8.1 and 8.2 inclusive



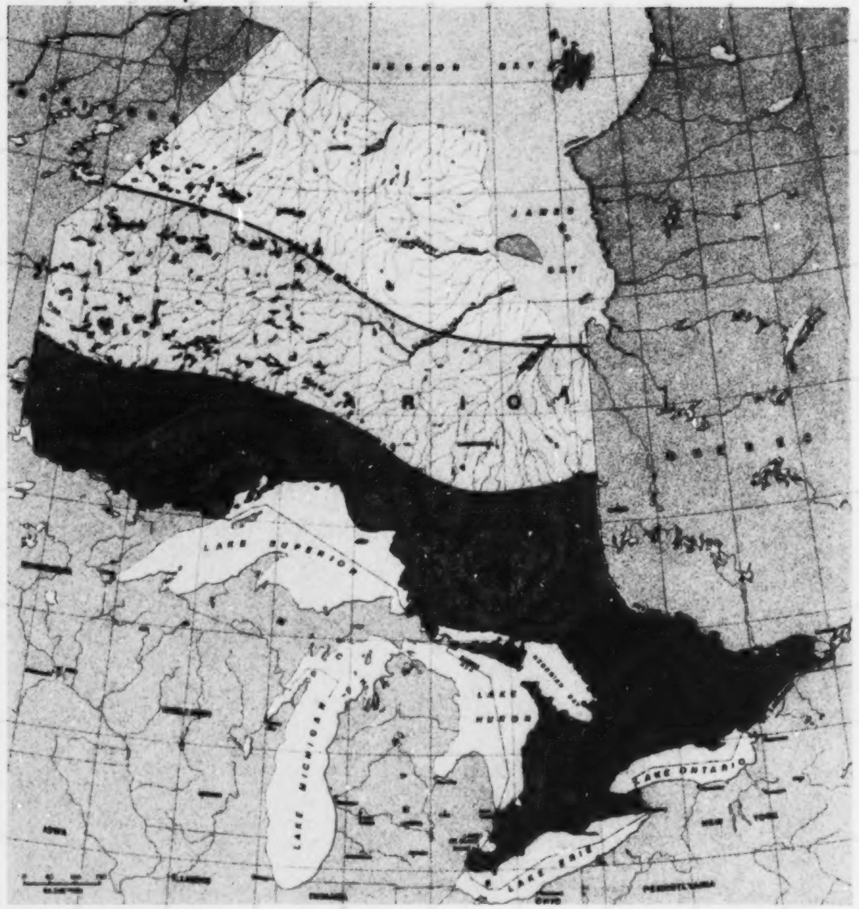
8.1 *Extent of Ice Cover on Great Lakes*





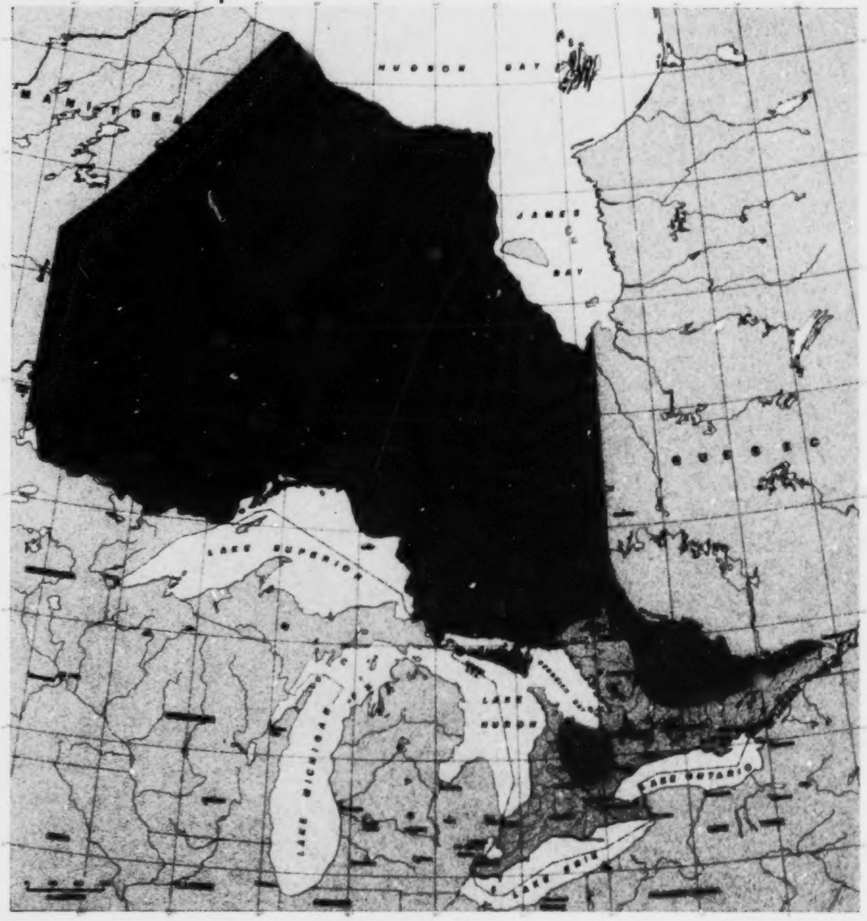
Lake Freeze-Up

HUDSON BAY
JAMES BAY
QUEBEC
MANITOBA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA



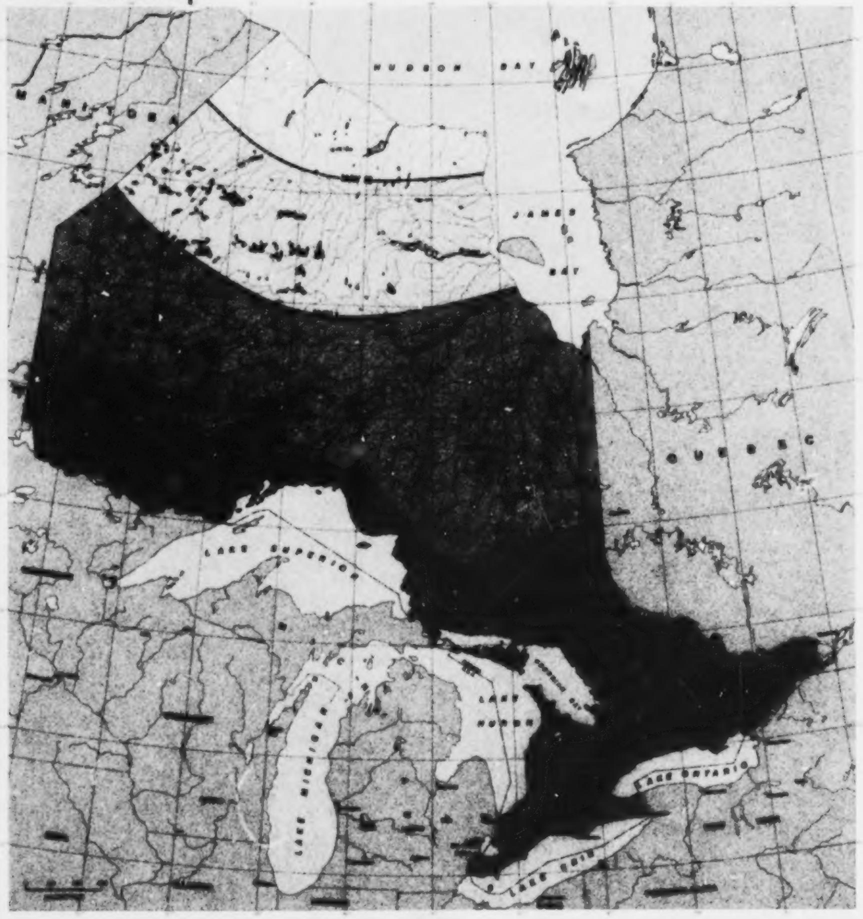
Lake Breakup

HUDSON BAY
JAMES BAY
ONTARIO
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA



River Freeze-Up

HUDSON BAY
JAMES BAY
MANITOBA
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE



River Breakup

HUDSON BAY
JAMES BAY
MANITOBA
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE

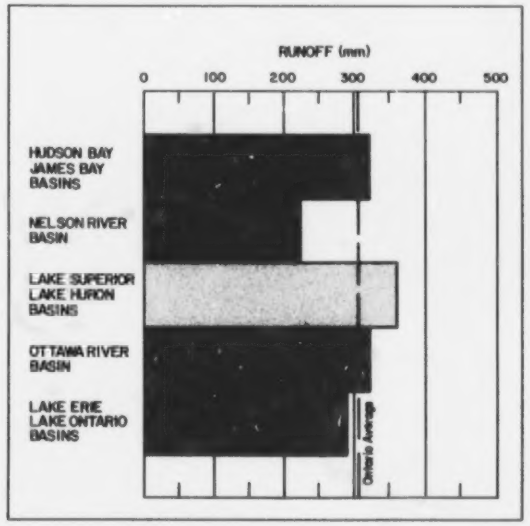
9 – Mean Annual Runoff

Runoff is that portion of precipitation which reaches rivers and lakes from surface drainage and ground water flow. The runoff amounts shown on the map opposite are expressed as a depth of water averaged over the drainage basin area. The mean annual runoff depth (mm) is derived from the mean annual flow in cubic metres per second (m^3/s) at the outlet from the basin and the area of the drainage basin (km^2).

The isolines were compiled using the runoff maps referenced below, which were developed using Ontario streamflow data and the corresponding drainage basin areas.

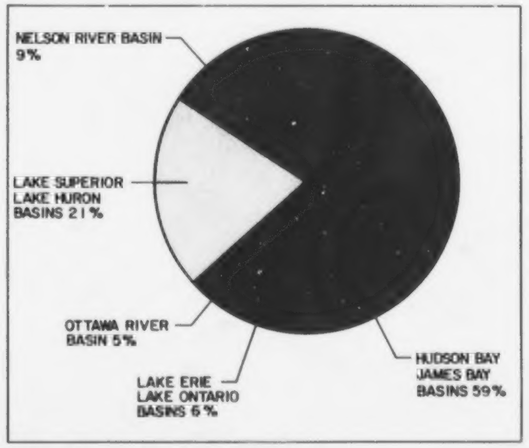
Ontario's mean annual runoff is 309 mm (12.2 in.) or 43 per cent of the mean annual precipitation. The runoff varies from a low of 200 mm in the western part of the province to a high of 500 mm east of Lakes Superior and Huron. The runoff for the Lake Erie/Lake Ontario basins shown in Figure 9.1 is below the Ontario average, whereas the precipitation shown on page 16 for the same basins is above the Ontario average. This directly reflects the higher amount of evapotranspiration for the Lake Erie/Lake Ontario basins. By comparison, about 20 per cent of Canada has a mean annual runoff in the range of 200 to 500 mm. Comparative annual runoff figures for specific areas in Canada are

– British Columbia coast	– 1,000 to 3,200 mm
– Alberta and Saskatchewan prairies	– less than 50 mm
– Maritime provinces	– 700 to 1,400 mm.



9.1 Mean Annual Runoff

The volume of the mean annual runoff is 301 km^3, or about 60 per cent of the volume of water in Lake Erie. If this water was released uniformly throughout the year at one outlet from the province, the flow would be 9,530 m^3/s (336 500 cubic feet per second – cfs). Figure 9.2 shows that approximately 68 per cent of the total runoff occurs in the Hudson Bay/James Bay and Nelson River basins. Only 6 per cent of the mean annual runoff occurs in the Lake Erie/Lake Ontario basins where industries and population are concentrated.



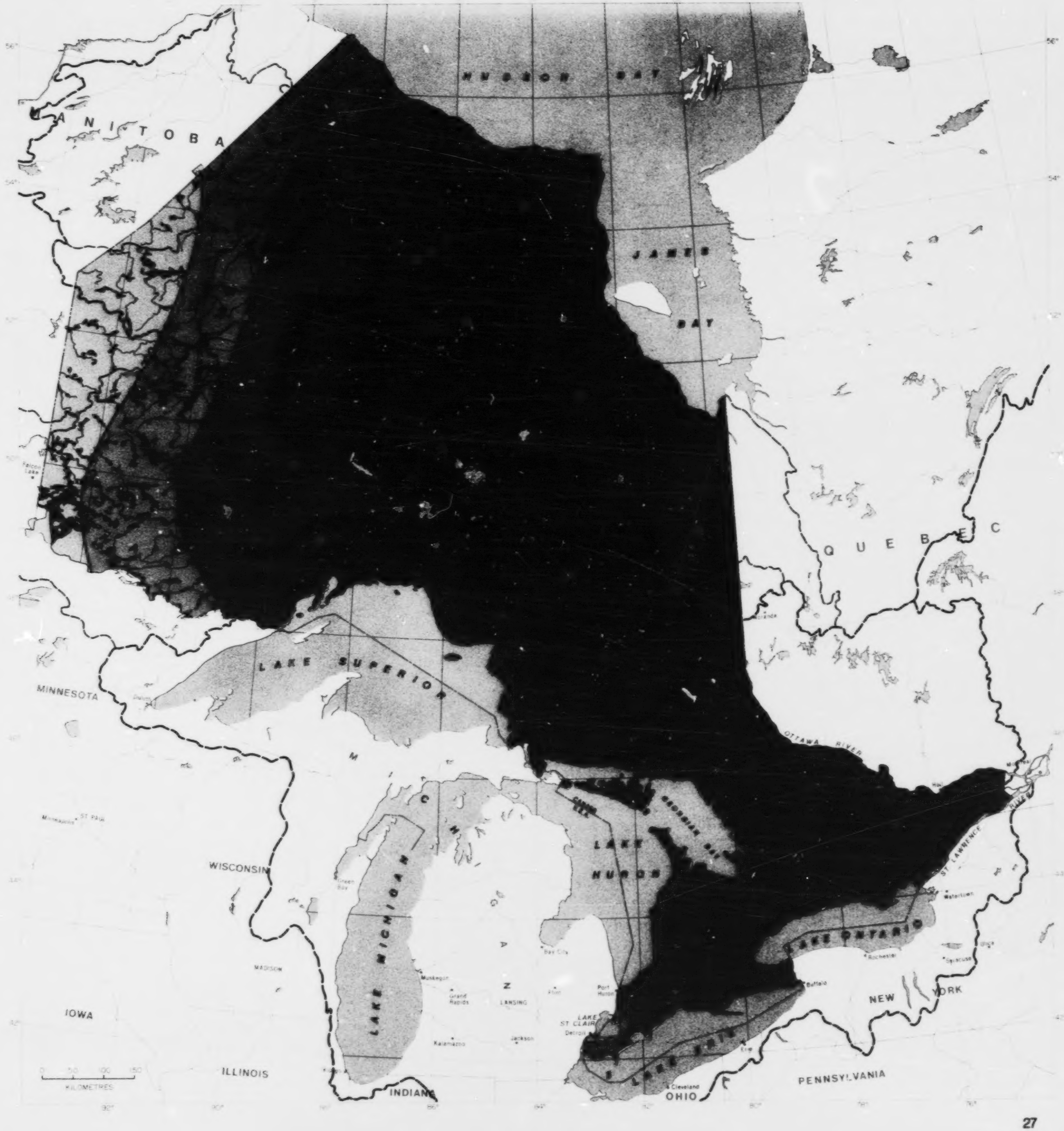
9.2 Distribution of Runoff Volume

The total runoff from the Great Lakes basin (including the United States portion) is 290 mm (11.4 in.) averaged over the total basin area. The Ontario contribution to the basin runoff, including the net precipitation on the Great Lakes, is 301 mm (11.9 in.). On a volumetric basis, Ontario contributes 43 per cent of the Great Lakes basin runoff from 42 per cent of the basin drainage area. The United States contribution is 57 per cent of the runoff from 58 per cent of the drainage area.

References listed on page 34:

- 9.1 and 9.2

MEAN ANNUAL RUNOFF
(mm)
200
250
300
350
400
450
500
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
OTTAWA RIVER
ST LAWRENCE RIVER
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ST CLAIR
LAKE ERIE
NEW YORK
PENNSYLVANIA
OHIO
INDIANA
ILLINOIS
IOWA
Minneapolis
ST PAUL
MADISON
Green Bay
Muskegon
Grand Rapids
LANSING
Kalamazoo
Jackson
Flint
Bay City
Port Huron
Detroit
Cleveland
Erie
Buffalo
Rochester
Syracuse
Watertown
0 50 100 150
KILOMETRES

10 – Monthly Distribution of Runoff

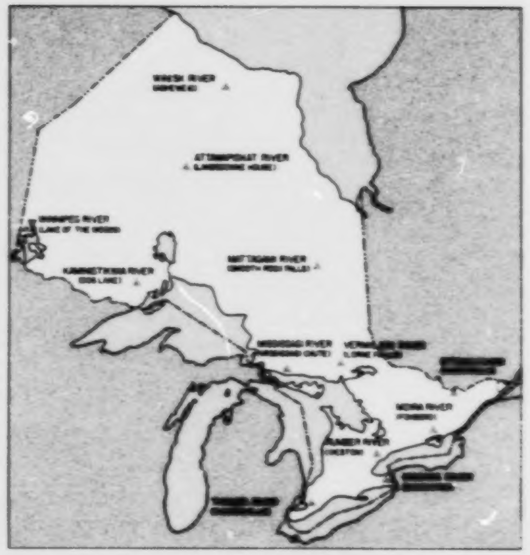
The monthly amount of runoff from an individual drainage basin is influenced by storage capacity in the basin, the amount of snow that accumulates during the winter and the rate at which snow and ice melts in the spring. If storage capacity is small relative to the volume of runoff in a basin, snowmelt or heavy rainfall will move very quickly through the basin.

The bar graphs opposite show the mean monthly runoff in millimetres for the 12 selected streamflow gauges shown in Figure 10.1. The flows at these gauges have been averaged over the appropriate drainage basin area to determine an equivalent depth in millimetres. Drainage areas are tabulated below. Maximum and minimum recorded monthly runoffs for each gauge are also noted. Gauges were chosen to correspond approximately with the precipitation stations used on page 17.

STREAMFLOW GAUGES

Gauge Name	Period of Record	Drainage Basin Area (km²)
Thames River at Thamesville	1955 – 1983	4 300
Niagara River at Queenston	1860 – 1983	686 000
Humber River at Weston	1945 – 1983	800
Vermilion River at Lorne Falls	1918 – 1983	4 070
Moira River near Foxboro	1915 – 1983	2 620
Ottawa River at Chats Falls	1915 – 1983	89 600
Kaministikwia River at outlet of Dog Lake	1923 – 1983	3 760
Mississagi River at Mississagi Chute	1961 – 1983	9 300
Mattagami River at Smooth Rock Falls	1920 – 1983	10 000
Winnipeg River below Lake of the Woods outlet	1892 – 1983	70 400
Attawapiskat River below Attawapiskat Lake	1966 – 1983	24 200
Winisk River below Asheweig River tributary	1965 – 1983	50 000

The bar graphs for the Winnipeg and Niagara rivers illustrate the flow regulation effect of drainage basins which contain substantial storage capacity. Runoff from month to month does not have a large variation and the ratio of maximum to minimum monthly runoff is not large. On the other hand, rivers such as the Attawapiskat and the Vermilion have monthly runoffs which vary directly with the amount of rainfall and snowmelt. In general, the large northern drainage basins have little regulation compared to the Great Lakes system. The regulation of runoff is very important in the study of surface water resources.



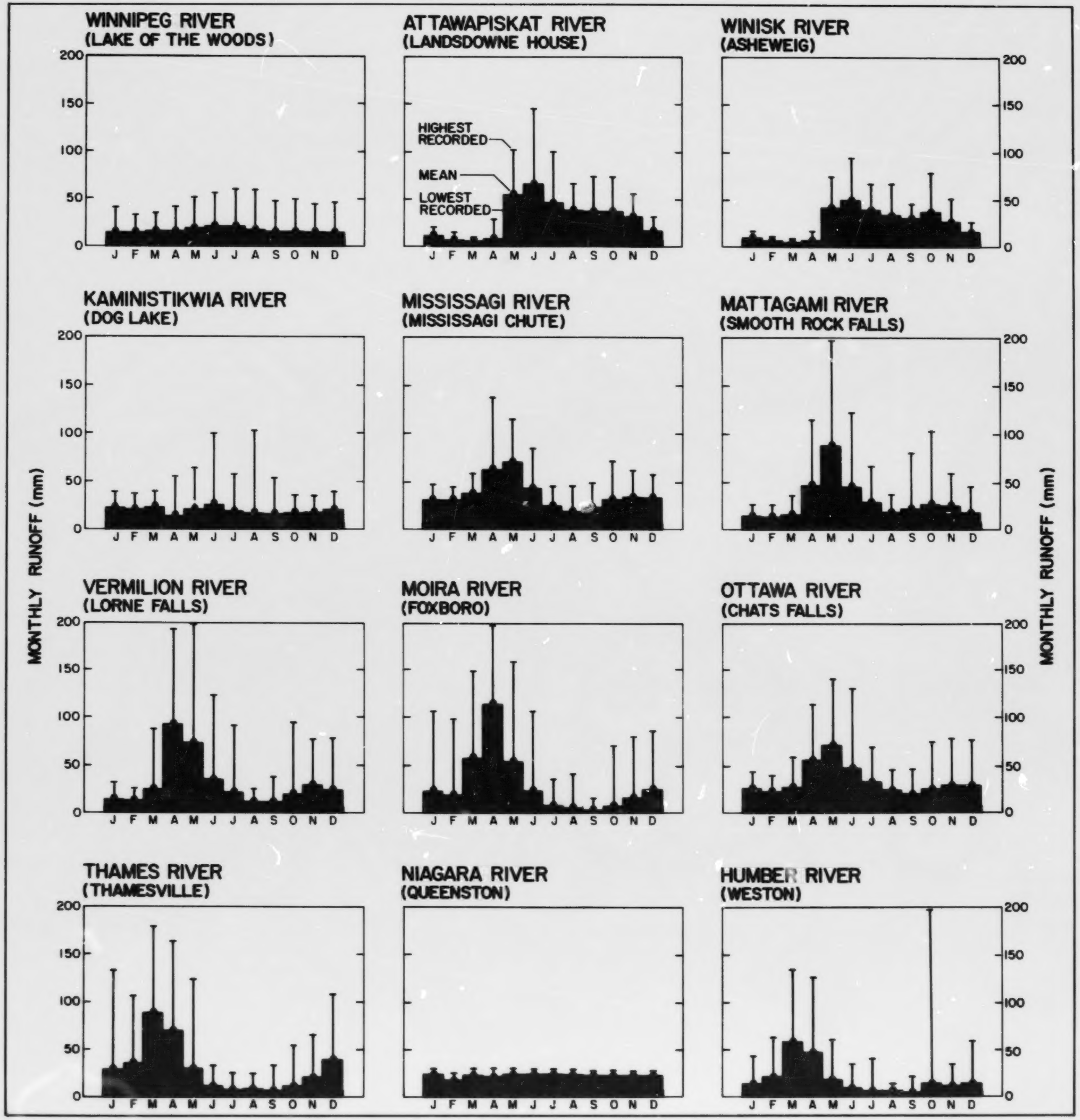
10.1 Locations of Selected Streamflow Gauges

The flow regulation effect of the Great Lakes system is very significant. If the flow out of Lake Superior were to be increased by 140 m³/s (5,000 cfs), it would take about 3 years for one-half of that flow increase to be noticed at the outlet of Lake Ontario. The large surface area of the Great Lakes accounts for this flow regulation.

A river may have a large annual runoff but if it cannot be controlled to hold back flood flows for release at a later date, the runoff which can be depended on throughout the year will be much lower than the mean annual runoff. This is particularly important for planning hydroelectric developments, municipal water supplies and other projects where a firm supply of water is required.

References listed on page 34:

- 10.1 to 10.3 inclusive


WINNIPEG RIVER
(LAKE OF THE WOODS)
ATTAWAPISKAT RIVER
(LANDSDOWNE HOUSE)
WINISK RIVER
(ASHEWEIG)
HIGHEST RECORDED
MEAN
LOWEST RECORDED
KAMINISTIKWIA RIVER
(DOG LAKE)
MISSISSAGI RIVER
(MISSISSAGI CHUTE)
MATTAGAMI RIVER
(SMOOTH ROCK FALLS)
VERMILION RIVER
(LORNE FALLS)
MOIRA RIVER
(FOXBORO)
OTTAWA RIVER
(CHATS FALLS)
THAMES RIVER
(THAMESVILLE)
NIAGARA RIVER
(QUEENSTON)
HUMBER RIVER
(WESTON)
MONTHLY RUNOFF (mm)
0
50
100
150
200
J F M A M J J A S O N D

11 – Mean Annual River Flows

It was noted on page 26 that if the mean annual runoff for the province was concentrated into 1 river, the flow in that river would be 9,530 m^3/s (336 500 cfs) throughout the year. The map opposite illustrates how this mean annual runoff is actually distributed throughout the many rivers across Ontario. All rivers having a mean annual flow larger than 50 m^3/s (1,760 cfs) are shown. The width of the arrow shown on each river represents the estimated mean annual flow at any point along the river.

Major flow diversions from north flowing rivers are described in Figure 11.1.

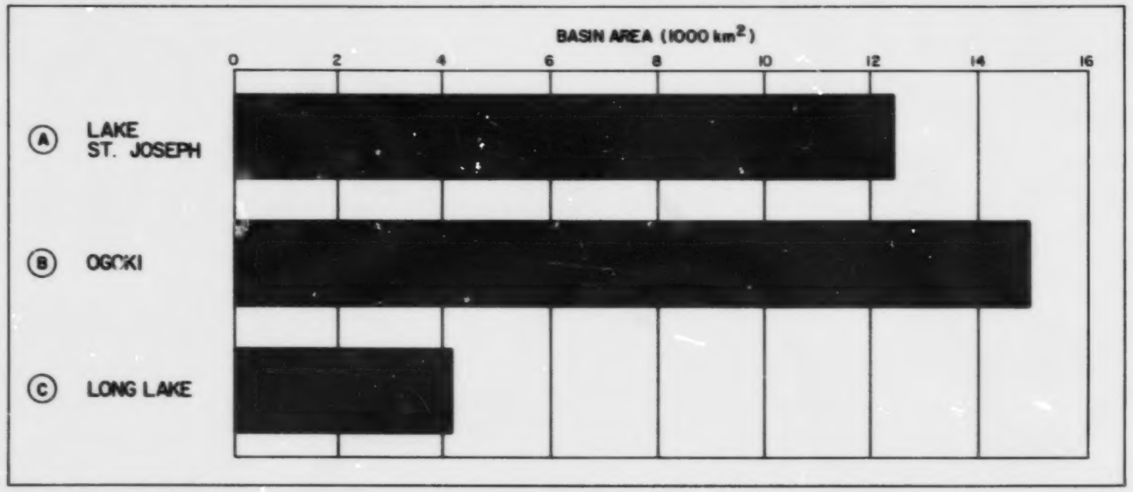
The sum of all flows at the mouths of the rivers shown on the map is considerably greater than 9,530 m^3/s because these flows include significant contributions from portions of the drainage basins in adjacent provinces and states.

In addition to the mean annual river flows, flood flows and low flows are shown at some selected streamflow stations. The flood flow that has been chosen is the average daily flow that will be exceeded, on average, once in 20 years of record. The low flow illustrated is the average flow over a period of 7 consecutive days that will be exceeded, on average, in 19 out of 20 years of record. These flood and low flows give a general indication of the range of river flows which can be expected.

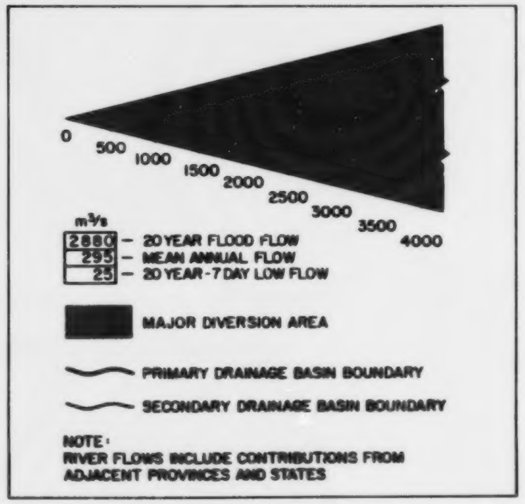
The flow distribution throughout the province indicates that large supplies of surface water occur in the northern parts of the province, away from the heavily populated areas of the lower Great Lakes. However, it should be noted that the flows in the northern rivers vary significantly from season to season, as discussed on page 32. Any consideration of flow diversions from the north flowing rivers must recognize this variability of flow.

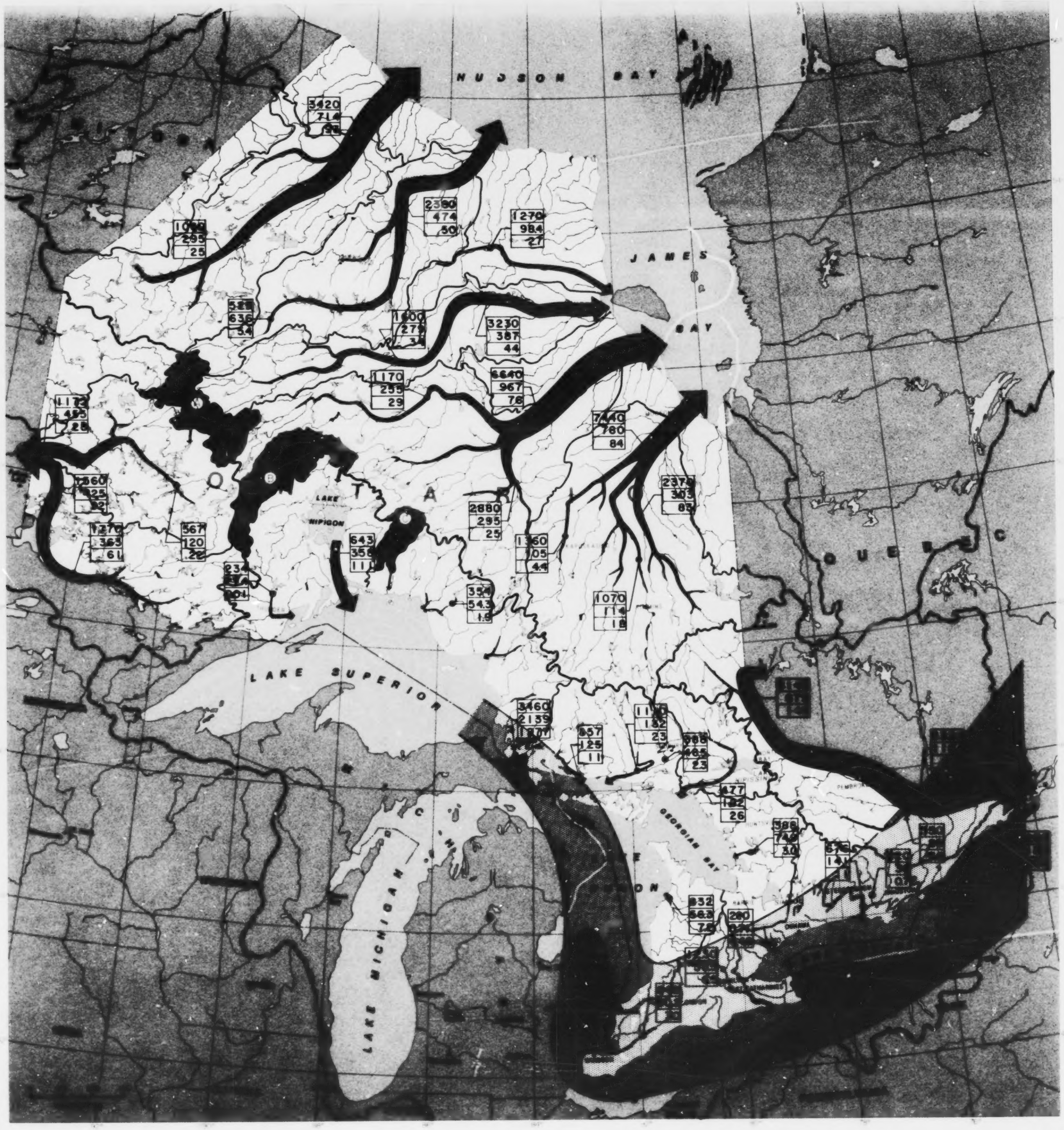
References listed on page 34:

- 11.1 to 11.3 inclusive



11.1 *Major Diversions*

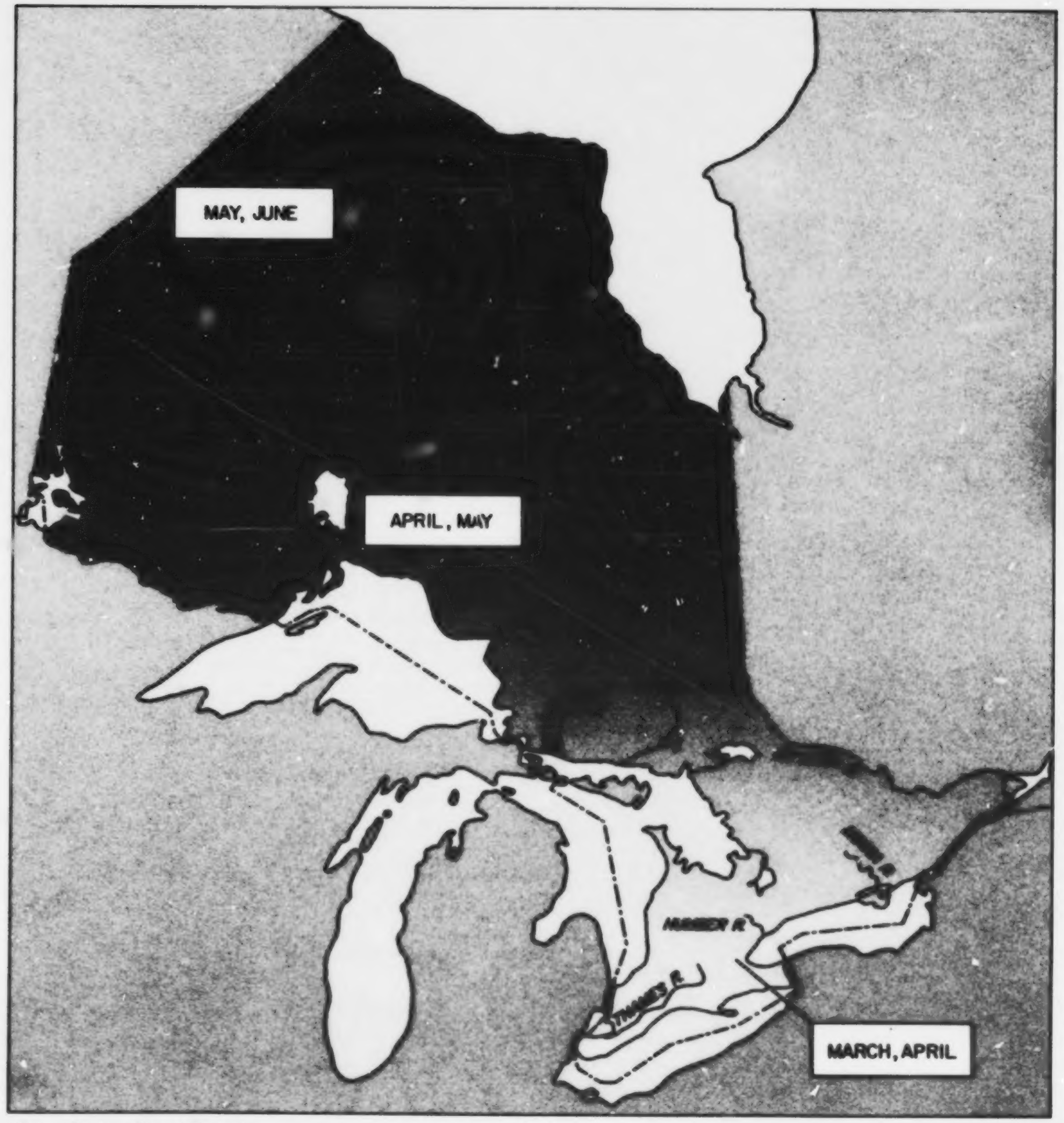

0
500
1000
1500
2000
2500
3000
3500
4000
m³/s
2880 – 20 YEAR FLOOD FLOW
295 – MEAN ANNUAL FLOW
25 – 20 YEAR - 7 DAY LOW FLOW
MAJOR DIVERSION AREA
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY
NOTE:
RIVER FLOWS INCLUDE CONTRIBUTIONS FROM ADJACENT PROVINCES AND STATES


HUDSON BAY
JAMES BAY
ONTARIO
QUEBEC
LAKE NIPIGON
LAKE SUPERIOR
LAKE MICHIGAN
GEORGIAN BAY
3420 714 98
1020 295 25
2390 474 50
1270 98.4 27
1600 275 34
3230 387 44
1170 255 29
6640 967 78
7440 780 84
567 120 22
643 358 11
2880 295 25
2370 303 85
1360 105 44
354 54.3 1.5
1070 114 18
557 125 11
477 132 26

12 – Seasonal River Flows

The maps opposite show the distribution of seasonal average river flows in the same manner as on page 31. These maps show, in general, that all major river flows are highest during the spring melting season of April, May and June. The seasons of lowest flows are generally summer and fall in the southern part of the province and winter in the far north. Evapotranspiration is responsible for the low flows in the south. In the north, low flows in the winter result from the extremely low temperatures, which cause precipitation to be stored as snow and inhibit surface and ground water movement.

The selection of specific months to represent each season is significant. Referring to page 29, the timing of spring floods can be generalized as shown in Figure 12.1.


MAY, JUNE
APRIL, MAY
HUMBER R.
THAMES R.
MARCH, APRIL

12.1 *Spring Flood Periods*

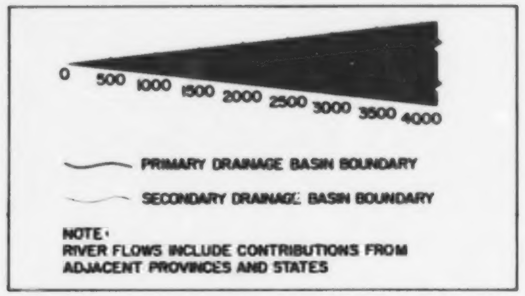
The months that have been selected for the seasonal maps give a good indication of seasonal flow variation for most rivers.

In southern Ontario, low river flows in the summer and fall reduce the amount of water available to assimilate return flows from municipalities, for recreational uses and for peak municipal and irrigation demands.

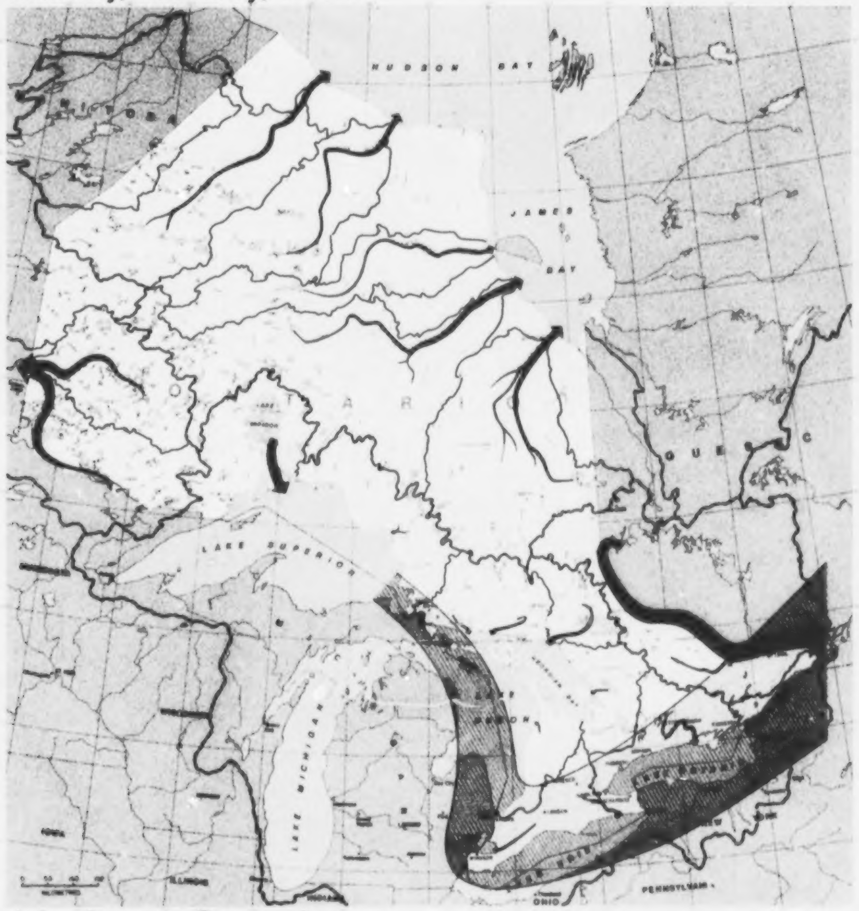
The storage capacity available in the Great Lakes system is reflected by the extremely uniform flow through the system from season to season. This uniform flow throughout the year is very important to the industrial and urban developments on the lower Great Lakes which require reliable water supply.

References listed on page 34:

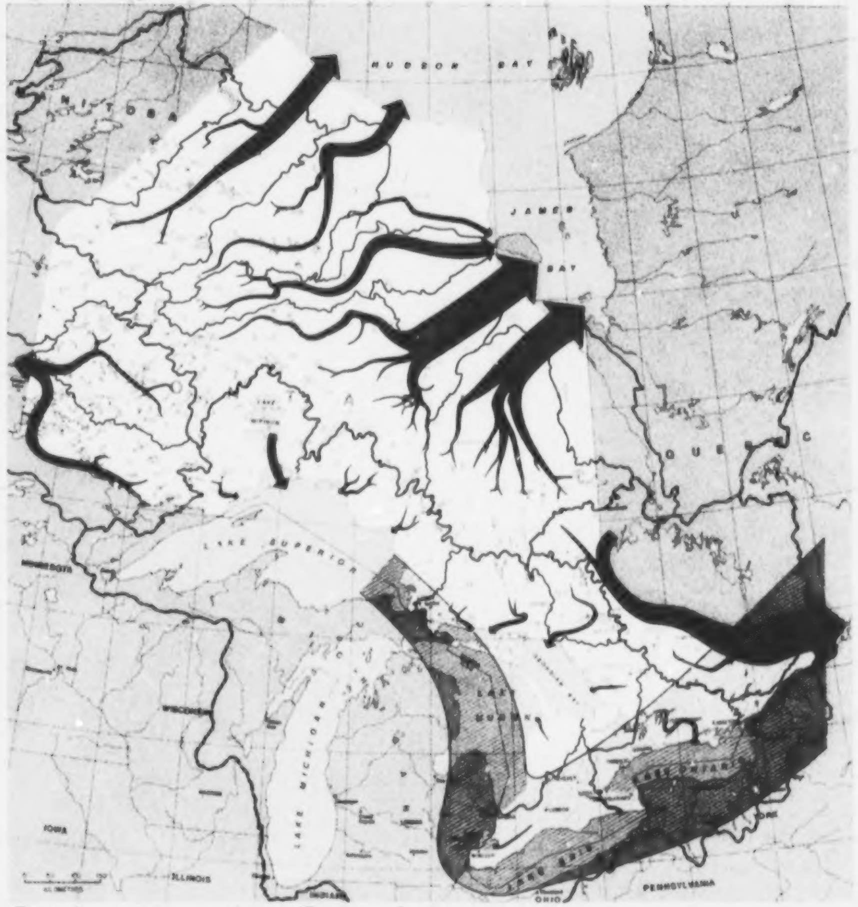
- 12.1 and 12.2


0
500
1000
1500
2000
2500
3000
3500
4000
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY
NOTE:
RIVER FLOWS INCLUDE CONTRIBUTIONS FROM
ADJACENT PROVINCES AND STATES

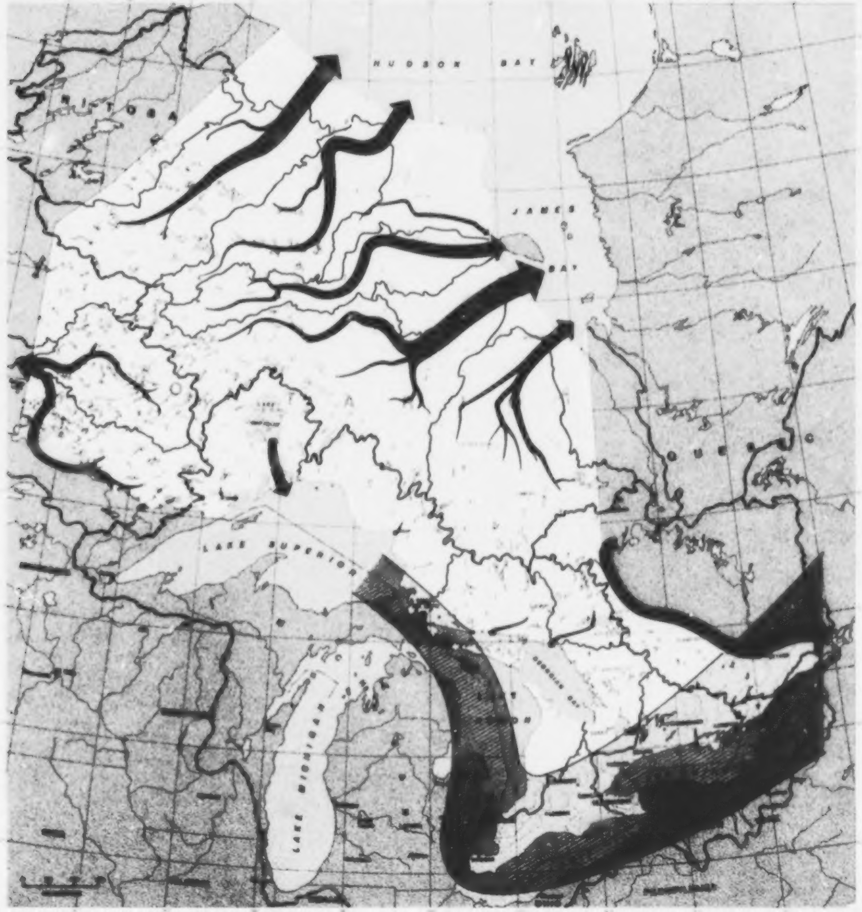
January, February, March


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
OHIO
PENNSYLVANIA

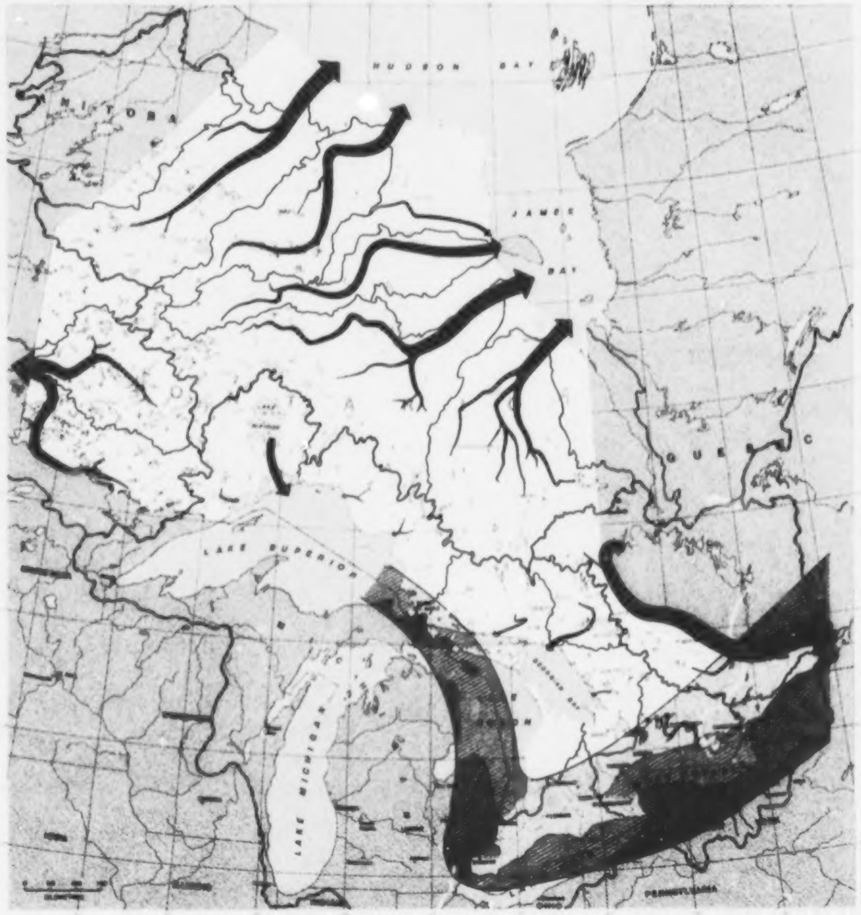
April, May, June


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
IOWA
ILLINOIS
OHIO
PENNSYLVANIA

July, August, September


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN

October, November, December


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN

List of References

1.1 Ministry of Treasury and Economics
Ontario Statistics, 1982

3.1 Water Survey of Canada, Ottawa,
Canada, 1983
HYDEX Computer Data File
Environment Canada Inland Waters
Directorate, Water Resources Branch

3.2 Cox, E.T., 1978
Counts and Measurements of Ontario
Lakes 1978
Fisheries Policy Development Section,
Fisheries Branch
Ministry of Natural Resources Ontario

4.1 Fisheries and Environment Canada, 1978
Hydrological Atlas of Canada
Map No. 3

5.1 Canada Department of the
Environment, 1970
Atmospheric Environment Service, Toronto
Manual of Standard Procedures for
Surface Weather Observing and
Reporting (MANOBS)
6th Edition

5.2 Seligman, G., 1936
Snow Structure and Ski Fields
MacMillan, London

5.3 Thomas, M.K., 1964
Snowfall in Canada
Canada Department of Transport,
Meteorological Branch, CIR 3977,
TEC 503

5.4 Manning, F.D., 1983
Winter Snowfall Averages and Extremes
at Principal Climatological Stations
Environment Canada, Atmospheric
Environment Service, CLI-5-83,
Downsview

6.1 Environment Canada
Canadian Climate Normals - Ontario,
Temperature and Precipitation
1951 to 1980
Atmospheric Environment Service

7.1 Viessman, W., Knapp, J.W., Lewis, G.L.,
and Horbough, T.E., 1977
Introduction to Hydrology, 2nd Edition,
New York

7.2 Fisheries and Environment Canada, 1978
Hydrological Atlas of Canada
Map No. 17

7.3 Richards, J.L. and Irbe, J.G., 1969
Estimates of Monthly Evaporation Losses
from the Great Lakes 1950 - 1968
Based on the Mass Transfer Technique
Proc. Twelfth Conf. Great Lakes Res.,
pp 469 - 487

8.1 Allen, W.T.R., 1977
Freeze-Up, Break-Up and Ice Thickness
in Canada
Fisheries and Environment Canada
Atmospheric Environment Service,
CLI-1-77, Downsview

8.2 Department of Fisheries and Oceans,
Ottawa, Canada, 1982
Sailing Directions - Great Lakes
Ninth Edition

9.1 Sangal, B.P. and Kallio, R.W., 1977
Magnitude and Frequency of Floods in
Southern Ontario
Fisheries and Environment Canada
Technical Bulletin Series No. 99, Ottawa

9.2 Department of the Environment,
Ottawa, 1972
Report on Assessment of Albany River
Power Potential
Northern Ontario Water
Resources Studies

10.1 Environment Canada, Water Survey of
Canada, 1980
Historical Streamflow Summary -
Ontario to 1979

10.2 Environment Canada, Water Survey of
Canada, 1980 - 1982
Surface Water Data - Ontario

10.3 Freeman, N.G. and Haras, W.S.
What You Always Wanted to Know About
Great Lakes Levels
Government of Canada
Fisheries and Oceans
Ocean and Aquatic Sciences

11.1 See 10.1 above.

11.2 See 10.2 above.

11.3 Water Survey of Canada, Ottawa, Canada,
1983
Computer Data File of Daily Discharge
Environment Canada, Inland Waters
Directorate, Water Resources Branch

12.1 See 10.1 above.

12.2 See 10.2 above.

GROUND WATER RESOURCES

Introduction

The value of ground water as a major source of supply is well recognized in Ontario in spite of the general abundance of surface water. Besides the fact that most rural water supplies in Ontario are obtained from wells, almost one-half of all municipal water supplies in the province are from ground water sources. Ground water is, therefore, of great continuing importance to the province.

The development of large quantities of ground water is limited to those locations where suitable aquifers exist. Where available in sufficient quantity, ground water can offer advantages over surface water supplies since minimum treatment is required, long, costly pipelines can be avoided, uniform temperature and water quality are often available, and with proper management, the supply is dependable at proven quantities.

Ontario does not contain thick extensive aquifers comparable, for example, to the Ogallala Aquifer in the United States. By comparison, aquifers in Ontario are small and local.

Ground water is a significant component of the hydrologic cycle. It moves through openings in subsurface materials and eventually discharges at the surface into streams, rivers and lakes. Ground water occurs to varying extents in all geologic materials, and those materials that are capable of yielding water to wells in usable quantities are called aquifers. Although some materials can contain large volumes of water, they may not allow water to be extracted at a usable rate. Therefore, the total volume of water contained in a geologic formation is not discussed in this publication, rather the discussion deals with the rate at which water can be withdrawn.

In the highly populated areas of southern Ontario, ground water resources have been developed extensively and a great deal of site-specific information is available for numerous aquifers. In northern Ontario, the low population has precluded extensive ground water development and the data available are correspondingly less than for southern Ontario.

The information contained in this section is a generalized view of the ground water quantity resources of the province. Much more detail is available in the references (listed on page 48) that have been used. Geologic materials that form the bedrock and the overburden throughout the province are described on pages 38 and 42, and ground water yields from these materials are described on pages 40 and 44. The mean annual ground water contribution to streamflow across the province is shown on page 47.

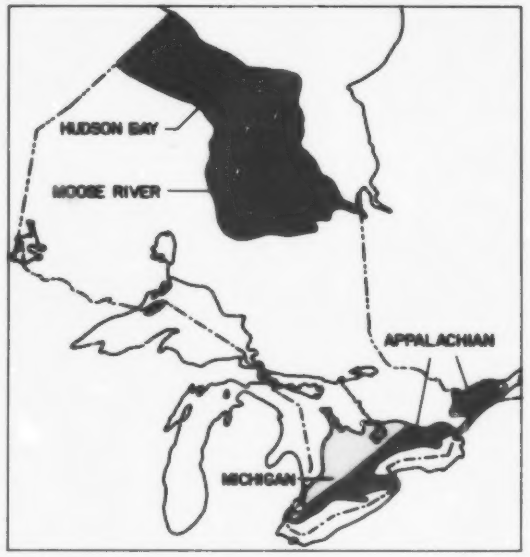
13 – Bedrock Geology

Certain hydraulic and physical characteristics of geologic materials determine how ground water is stored and how it moves through these materials. Therefore, it is necessary to know the occurrence and distribution of these materials and their water-related characteristics in order to discuss ground water occurrence, movement and availability to wells. There are two principal types of geologic materials, namely, bedrock and the unconsolidated material resting on bedrock known as overburden. For this discussion, bedrock geology, as shown on the map opposite, is grouped by age and rock type.

The Precambrian rocks represent the oldest known rocks in Canada and comprise igneous, metamorphic and sedimentary rock types. These rocks occur at or close to the surface over about two thirds of the province and are sometimes overlain by younger Paleozoic rocks as shown in Figure 13.1 which is a schematic cross-section of bedrock through southern Ontario. The Precambrian bedrock, commonly referred to as the Canadian Shield in areas of the province where it outcrops, extends into Quebec and Manitoba and into the United States.

In general, Precambrian rocks have undergone a series of geologic processes that involve high temperature or pressure, which has resulted in massive, dense rock formations. Openings in these rocks are usually very narrow and occur mainly along fractures or faults which are not necessarily interconnected. Wide variations in geologic structure and composition can result in a variety of fracture patterns, some of which may be very localized.

The younger Paleozoic rocks were deposited in relatively flat lying beds at the bottom of ancient seas. In Ontario these rocks occur in 4 basins, as shown in Figure 13.2, which provide a significantly better environment for ground water occurrence and movement than the Precambrian rocks.



13.2 Paleozoic Basins

Depending on the rock type, the number and extent of openings in Paleozoic rocks vary widely. Shale tends to have relatively few, wide openings, while limestone and dolostone often have extensive fracture patterns with much wider openings than in shale. Sandstone can be tightly cemented with few cracks, but at some locations sandstone contains numerous interconnected spaces among individual sand grains.

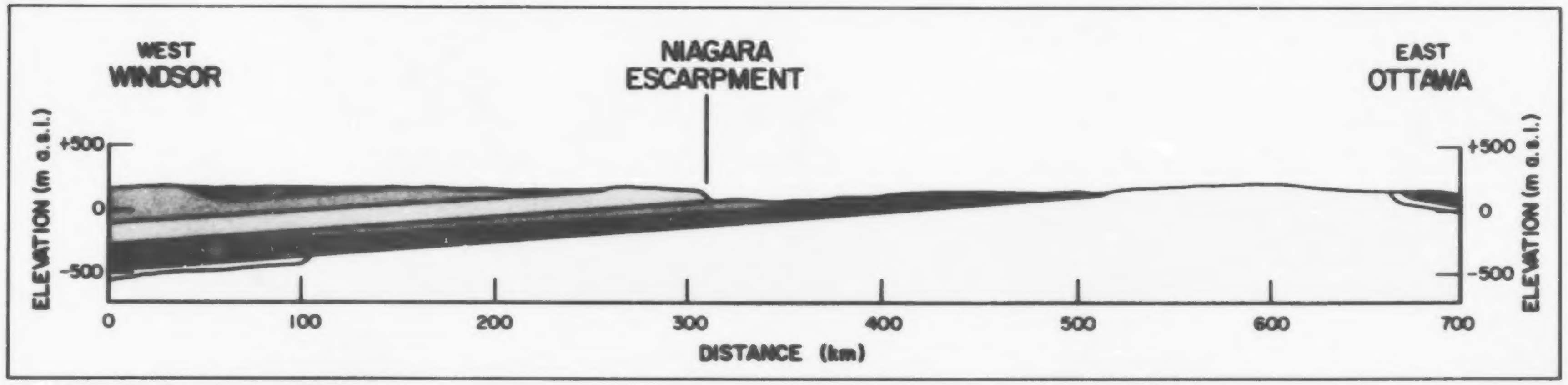
Cretaceous rocks in the Moose River basin are poorly consolidated and consequently open spaces in these rocks occur between individual grains of material similar to unconsolidated material such as sand, gravel, clay and silt.

Limestones and dolostones, and to a lesser extent sandstones, have the widest and most extensive openings. Therefore, these rocks are most important in terms of ground water storage and movement. Shale usually has few fractures that can transmit water at high rates, and similarily Precambrian rocks generally have few openings and therefore cannot readily transmit large volumes of water.

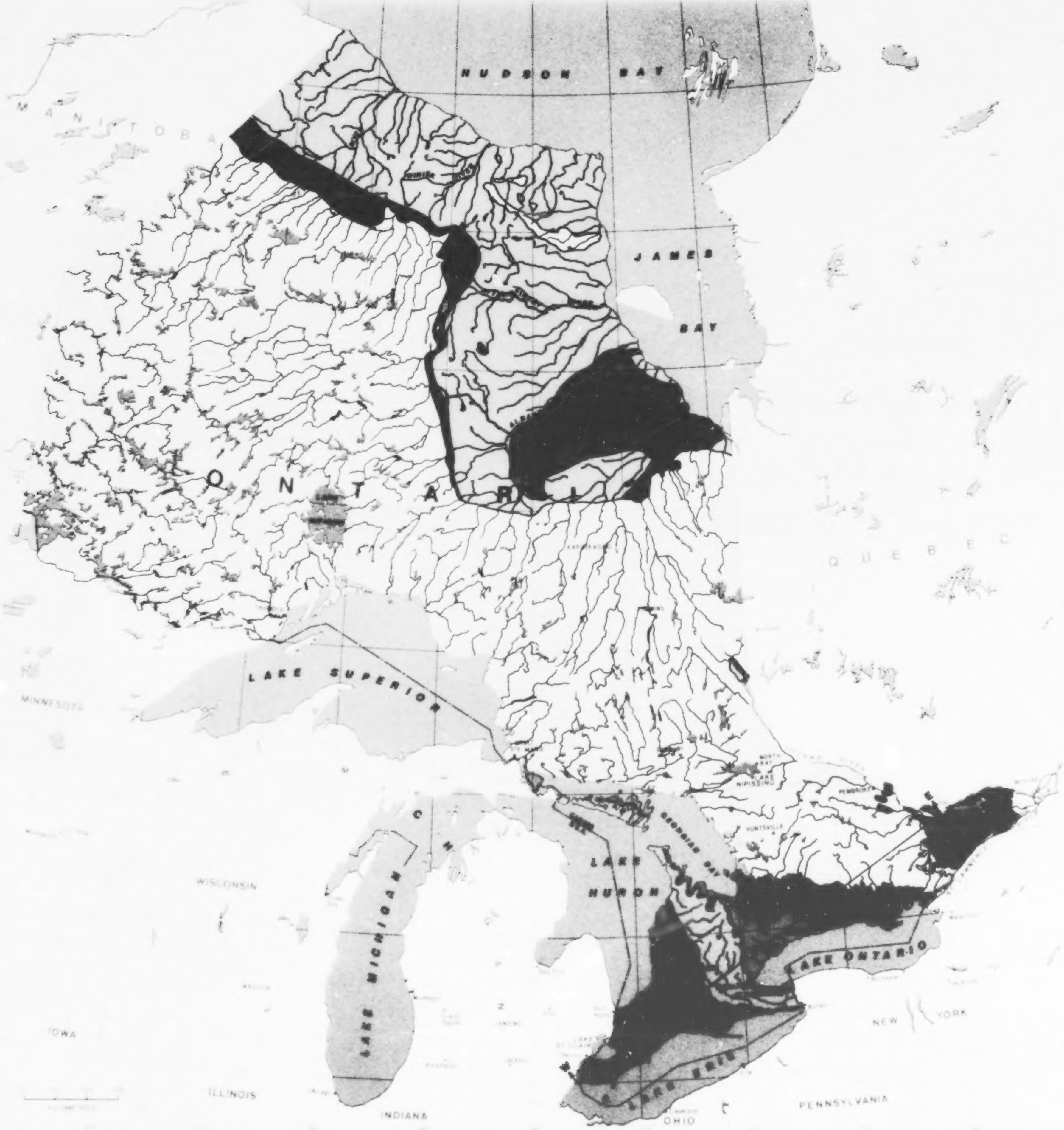
References listed on page 48:

- 13.1 to 13.7 inclusive

	AGE		PREDOMINANT MATERIAL
░	CRETACEOUS	–	CLAY, SAND AND LIGNITE
▓	DEVONIAN	–	SHALE, MINOR LIMESTONE
■	DEVONIAN	–	LIMESTONE AND DOLOSTONE
░	SILURIAN	–	DOLOSTONE, MINOR SANDSTONE, SHALE, EVAPORITES
▒	ORDOVICIAN	–	SHALE, MINOR LIMESTONE
■	ORDOVICIAN	–	LIMESTONE, MINOR DOLOSTONE, SANDSTONE, SHALE
□	CAMBRIAN	–	SANDSTONE
□	PRECAMBRIAN	–	IGNEOUS, METAMORPHIC, SEDIMENTARY ROCKS
〰	NIAGARA ESCARPMENT		
W ⌊⌋ E	SCHEMATIC CROSS SECTION OF BEDROCK		



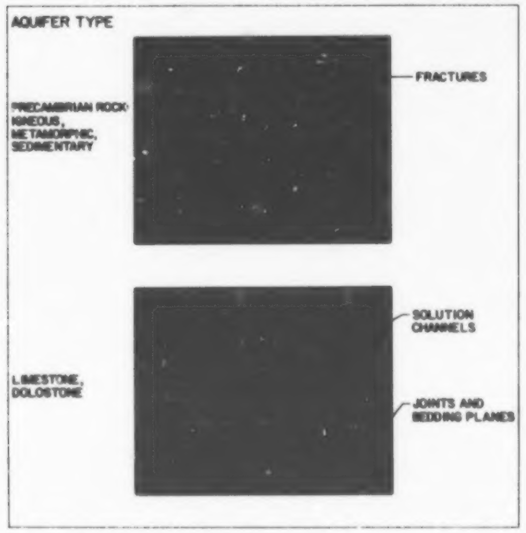
13.1 Schematic Cross-Section of Bedrock


HUDSON BAY
MANITOBA
JAMES BAY
ONTARIO
QUEBEC
LAKE SUPERIOR
MINNESOTA
NORTH BAY
LAKE NIPISSING
PEMBROKE
HUNTSVILLE
GEORGIAN BAY
LAKE HURON
MICHIGAN
WISCONSIN
LAKE MICHIGAN
LAKE ONTARIO
NEW YORK
IOWA
ILLINOIS
INDIANA
OHIO
LAKE ERIE
PENNSYLVANIA

14 – Ground Water Yields from Bedrock

Two characteristics, porosity and permeability, determine whether a specific geologic formation can be identified as an aquifer. Porosity is a measure of the open space contained in a geologic material and is usually expressed as a percentage of the total volume of the material. Permeability is a measure of the ability of a geologic material to transmit water and is expressed as a rate of water movement. High porosity indicates a good potential for storage and high permeability indicates a good potential for withdrawal by wells. The proper combination of porosity and permeability is required before a geologic formation can be considered an aquifer.

Fractures in bedrock can give high permeability values when they are wide and interconnected. The porosity, on the other hand, is usually related to fracture opening only and is fairly low (less than 5 per cent) in all rock types. The patterns of openings that form conduits for ground water flow in bedrock are illustrated in Figure 14.1. Wells that are drilled into bedrock must intersect at least 1 opening in order to yield water.


AQUIFER TYPE
PRECAMBRIAN ROCK: IGNEOUS, METAMORPHIC, SEDIMENTARY
FRACTURES
LIMESTONE, DOLOSTONE
SOLUTION CHANNELS
JOINTS AND BEDDING PLANES

14.1 Ground Water in Bedrock

The total volume of water stored in rocks does not necessarily mean that the water is readily available to wells. Rather the rate of withdrawal, termed "well yield", is the significant factor that determines usable quantities.

For purposes of indicating the availability of ground water throughout the province (see map opposite), 3 ranges of well yields have been selected to reflect the usual amounts of water necessary for the most common uses.

Well yields less than 1 litres per second (L/s) are generally suitable for most domestic purposes. Yields between 1 and 4 L/s can be adequate for expanded farming operations, small-scale irrigation and limited commercial enterprises. Yields greater than 4 L/s are generally necessary for municipal, industrial and large-scale agricultural purposes.

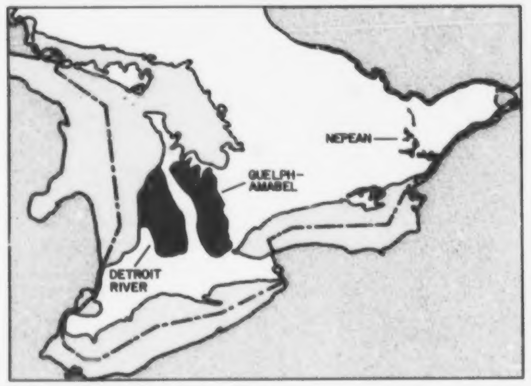
Wells drilled into the Precambrian rocks commonly yield 1 L/s (13 imp gal/min) or less due to low permeability. Generally, there are no known major aquifers on the Canadian Shield. At some locations, where the rock is highly faulted and fractured, wells yielding in excess of 16 L/s have been developed. However, these areas are rare.

Within the Paleozoic rocks, the Silurian dolostone, the Devonian limestone and dolostone, and the Cambrian sandstone generally have the highest permeabilities, and well yields are commonly in excess of 4 L/s. Ordovician limestones generally do not contain good aquifers, and shale of any age commonly yields less than 1 L/s. The Cretaceous rocks in the Moose River basin have not been extensively explored for water but are expected to have the potential for low well yields based on the types of rock present.

The only extensive regional bedrock aquifers with the potential for high water yields are within the Silurian dolostone (Guelph-Amabel Formation), the Devonian limestone and dolostone (Detroit River Formation) and the Cambrian sandstone (Nepean Formation). The locations of these formations are shown in Figure 14.2. In particular, the Guelph-Amabel Formation has been developed extensively to produce large quantities of water and is used for numerous municipal supplies. Generally, wells draw water from the upper 30 m (100 ft) of this formation where natural chemical dissolution has enlarged existing fractures and joints.

References listed on page 48:

- 14.1 to 14.4 inclusive



14.2 Major Bedrock Aquifers

WELL YIELDS

▨ LESS THAN 1 L/s

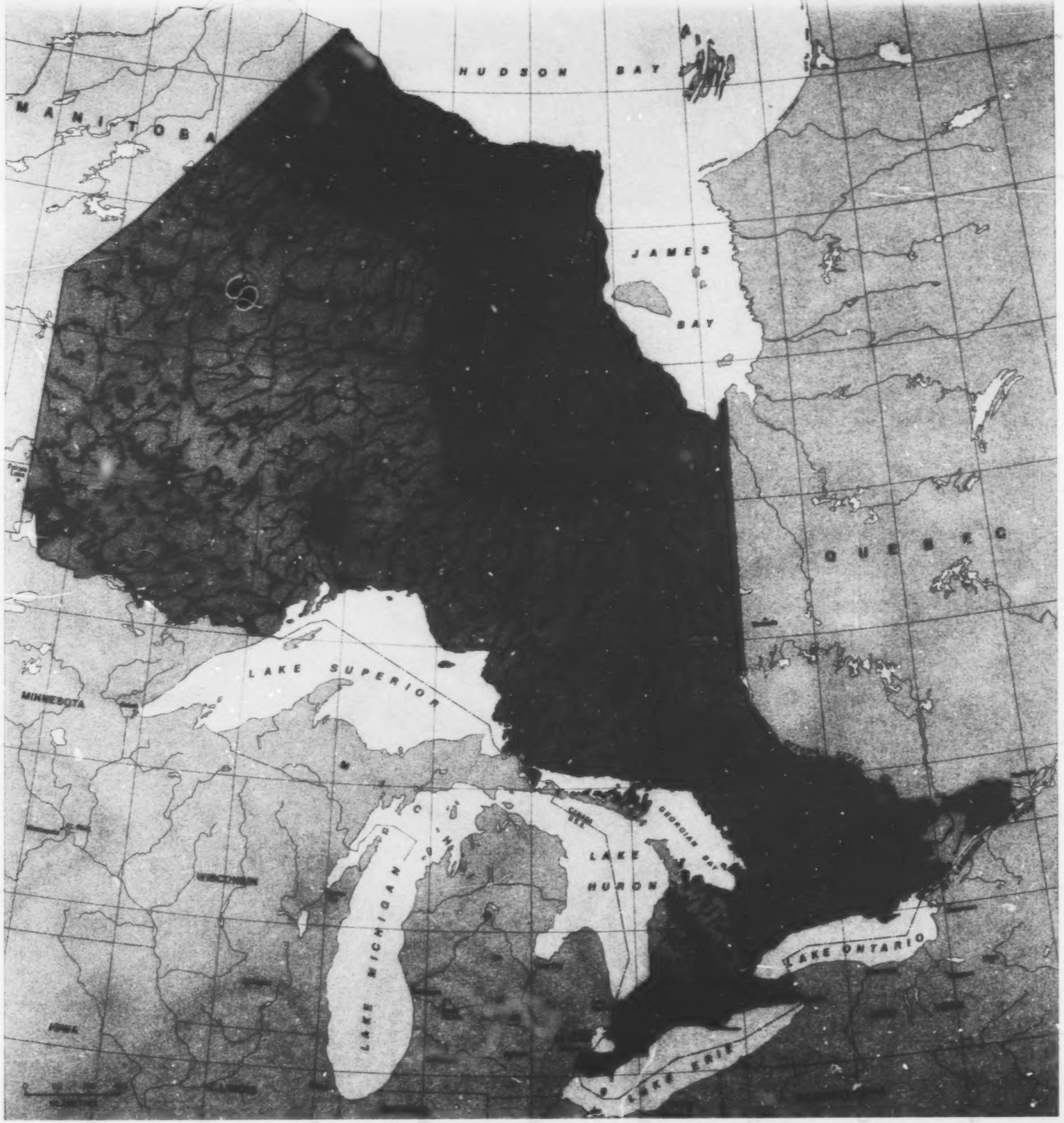
■ 1 TO 4 L/s

░ GREATER THAN 4 L/s

• WELLS KNOWN TO YIELD 16 L/s OR MORE

NOTE:

THE YIELDS INDICATED REPRESENT THE QUANTITIES OF WATER THAT COMMONLY ARE OBTAINED FROM INDIVIDUAL WELLS ON A SHORT TERM BASIS AND ARE ESTIMATED FROM INFORMATION CONTAINED IN WATER WELL RECORDS AND RELATED REFERENCES. A WELL DRILLED IN AN AREA MAY NOT NECESSARILY PRODUCE AT A RATE INDICATED.


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
IOWA

15 – Surficial Geology

An understanding of surficial geology is essential in discussion of ground water recharge, occurrence, movement and discharge. Areas of surficial sands and gravels permit rapid infiltration of precipitation to recharge ground water, while the same sand and gravel areas may act as important aquifers for local domestic supplies. Silts and clays, on the other hand do not allow rapid infiltration of precipitation.

During the past 1 million years, Ontario has been covered by glacial ice on at least 4 occasions. This activity has shaped the landscape and provided the surficial materials we see today. These materials include a mixture of sand, silt, clay and gravel deposited directly by the ice; silt, sand and gravel deposited by the meltwaters flowing off the ice, and silt and clay deposited in glacial lakes that were abundant in the province 10 000 to 20 000 years ago.

Sand and gravel have the largest openings between individual grains, and their ability to store and transmit ground water is the greatest of all the surficial materials. Sand and gravel deposits of varying sizes are found at scattered locations throughout the province as shown on the map opposite. Many of the larger deposits are in southcentral and southwestern Ontario where some layers are tens of metres thick. At certain locations the surficial sand and gravel deposits extend beneath silt and clay materials.

Many of the Northern Ontario surficial sand and gravel deposits form a thin veneer over bedrock or occur in long narrow ridges that are often dry. While these surficial sand and gravel deposits have been mapped at numerous locations, generally much less is known about the geology and water bearing characteristics of these deposits than of similar deposits in southern Ontario.

A large area of Ontario has only a thin layer of undifferentiated material or bedrock at the surface. This includes most of the Canadian Shield which is covered by a thin mixture of silt, sand and clay interspersed with areas of organic deposits (i.e., swamps and bogs) between the bedrock outcrops. These materials do not contain significant amounts of ground water.

Where the overburden is thick, such as in southwestern and some northern parts of Ontario, silt and clay predominate in the overburden as well as being the most common surficial materials. This is illustrated in Figure 15.1, which is a schematic cross-section of the overburden materials along a line from Lake Ontario to Georgian Bay. Unlike sand and gravel, silt and clay have low permeability and thus impede the infiltration of precipitation into the ground.

References listed on page 48:

- 15.1 to 15.6 inclusive

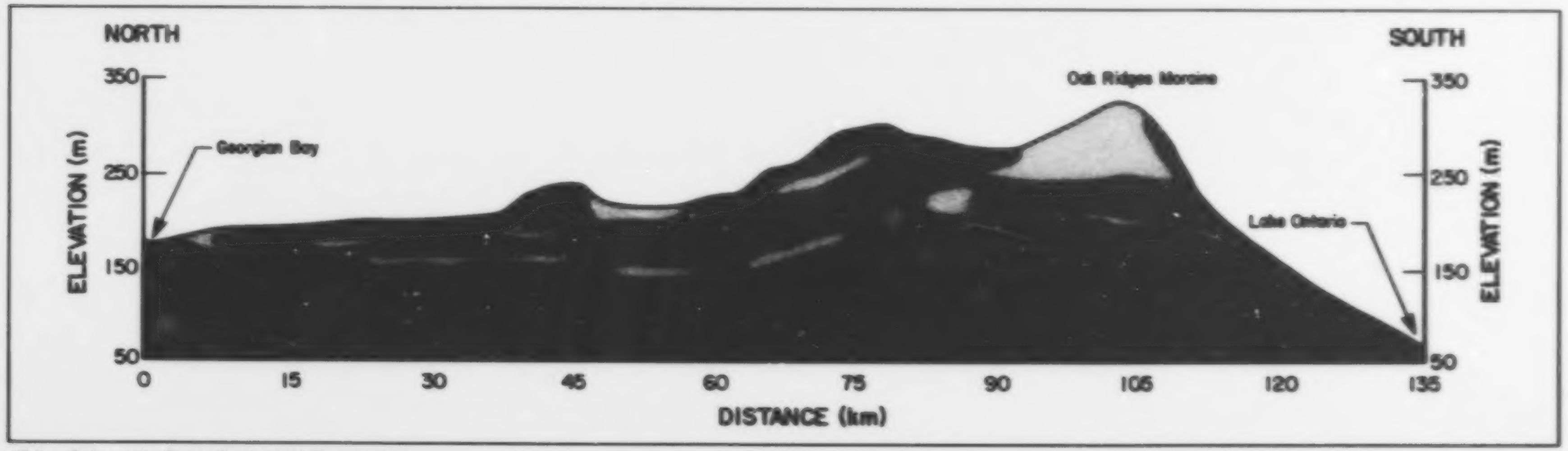
░ SANDS AND GRAVELS

■ SILTS AND CLAYS

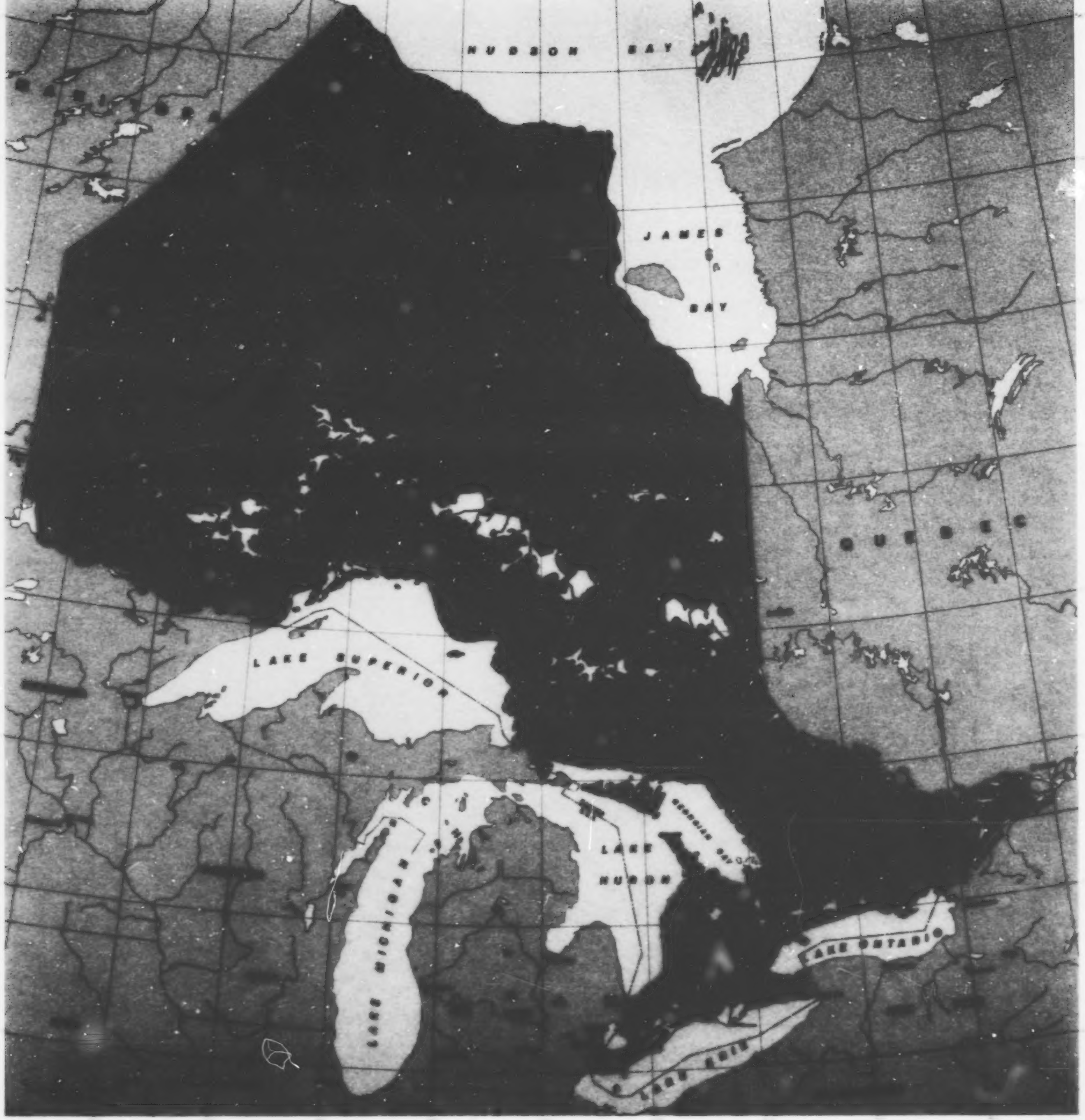
■ THIN UNDIFFERENTIATED MATERIAL OR BEDROCK

■ UNDIFFERENTIATED BEDROCK (CROSS SECTION ONLY)

N S SCHEMATIC CROSS SECTION OF OVERBURDEN



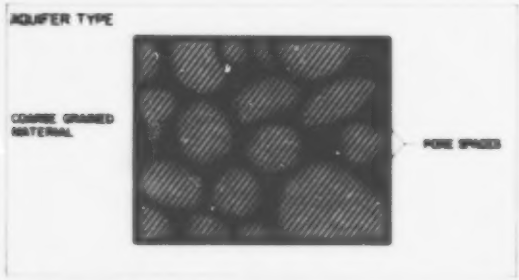
15.1 *Schematic Cross-Section of Overburden*


HUDSON BAY
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE

16 – Ground Water Yields from Overburden

Sand and gravel deposits form the principal aquifers in overburden. There are hundreds of these aquifers scattered throughout southern Ontario and they provide ground water supplies for domestic, agricultural and municipal purposes. Although many of these aquifers are small, they are nevertheless of great local significance. In Northern Ontario, the demand for ground water from sand and gravel deposits is considerably smaller and in many cases the potential of the deposits to yield water is not precisely known.

In contrast to ground water in fracture openings in bedrock, ground water in overburden materials occupies the spaces between individual grains of material as shown in Figure 16.1. Because there are usually a large number of these interstitial spaces, the porosity as well as the permeability of overburden materials such as sands and gravels is much higher than that of most bedrock. Because of the combination of large grain sizes and interconnected open spaces, sand and gravel deposits have the potential for highest permeabilities and consequently ground water yields (see map opposite).

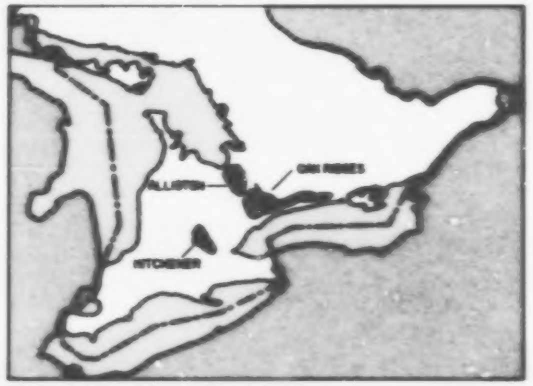


16.1 *Ground Water in Overburden*

Sand and gravel aquifers of major extent sustain numerous high-capacity wells in southcentral and southwestern Ontario. The largest of these aquifers includes the Oak Ridges Aquifer complex lying along an east-west axis north of Lake Ontario and the Alliston Aquifer complex south of Georgian Bay.

In addition, numerous local, high-capacity aquifers around Kitchener provide large quantities of ground water for municipal supplies (Figure 16.2).

Many large municipal ground water supplies in Ontario are obtained from aquifers in the overburden and the following list indicates some of these municipalities and the daily withdrawals of ground water.



16.2 *Major Overburden Aquifers*

Municipal Ground Water Supplies

Municipality Served	Minimum Ground Water Usage (1975 data) (1,000 m³/d)
London*	100.0*
Kitchener-Waterloo	75.0
Cambridge	35.0
Markham*	20.0*
Barrie	15.0
Woodstock	15.0
Vaughan*	10.0*
Richmond Hill*	10.0*
Georgetown	7.5
Newmarket	7.5
Elmira	7.5
Aurora	7.5
Kapuskasing	5.0
Blazard Valley	5.0

*Ground Water Source replaced by Surface Water Source

References listed on page 48

- 16.1 to 16.8 inclusive

WELL YIELDS

▨ LESS THAN 1 L/s

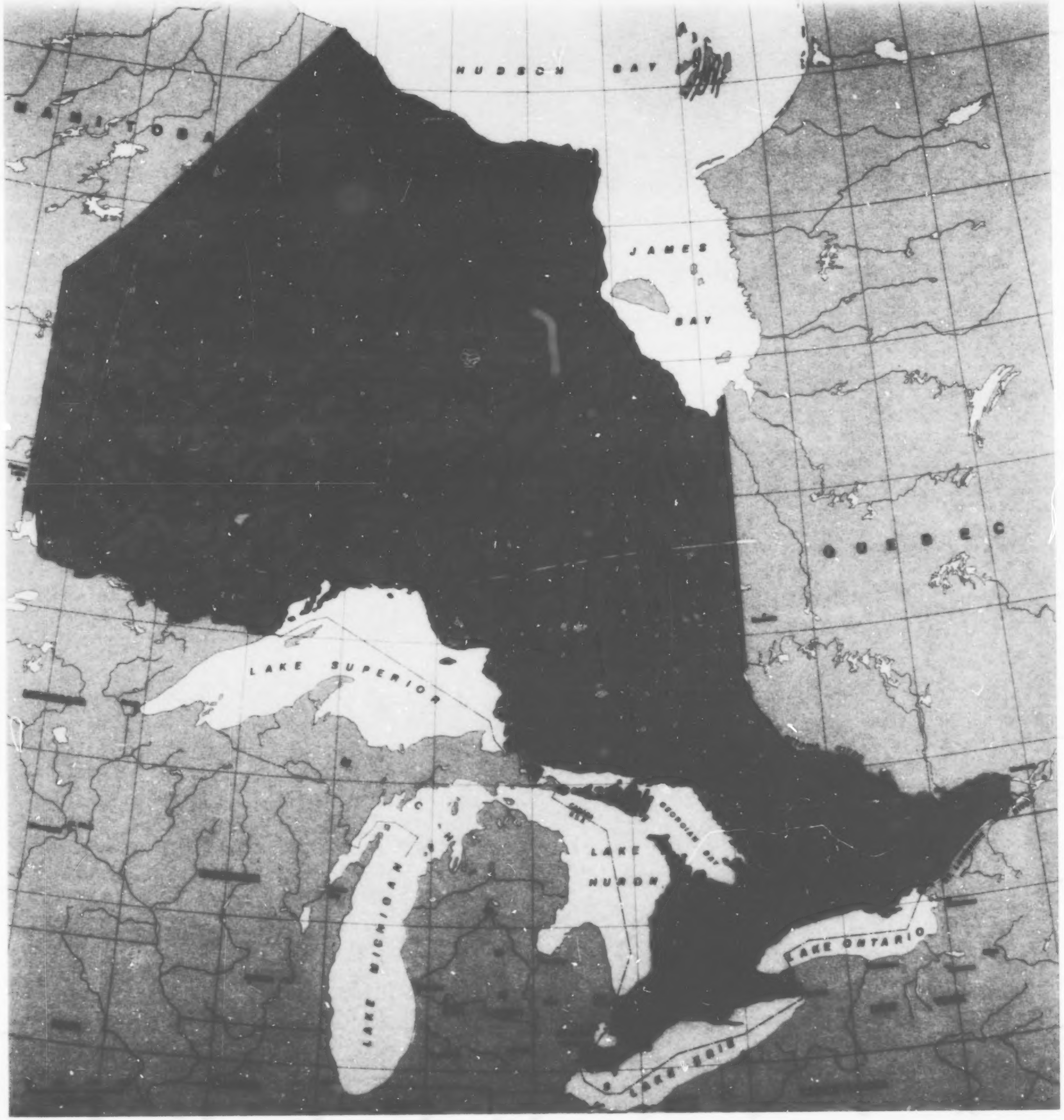
▨ 1 TO 4 L/s

▨ GREATER THAN 4 L/s

● WELLS KNOWN TO YIELD 15 L/s OR MORE

NOTE:

THE YIELDS INDICATED REPRESENT THE QUANTITIES OF WATER THAT COMMONLY ARE OBTAINED FROM INDIVIDUAL WELLS ON A SHORT TERM BASIS AND ARE ESTIMATED FROM INFORMATION CONTAINED IN WATER WELL RECORDS AND RELATED REFERENCES. A WELL DRILLED IN AN AREA MAY NOT NECESSARILY PRODUCE AT A RATE INDICATED.


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
LAKE SUPERIOR
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE

17 – Ground Water Contributions to Streamflow

In most parts of Ontario, ground water discharges into streams and provides a perennial portion of streamflow throughout the year. In fact, natural streamflow in many areas is sustained almost totally by ground water discharge during periods of low precipitation normally in the summer months. As such, the maintenance of natural ground water discharge to streams is an important water management consideration that requires a thorough knowledge of the relationship between streamflow and ground water.

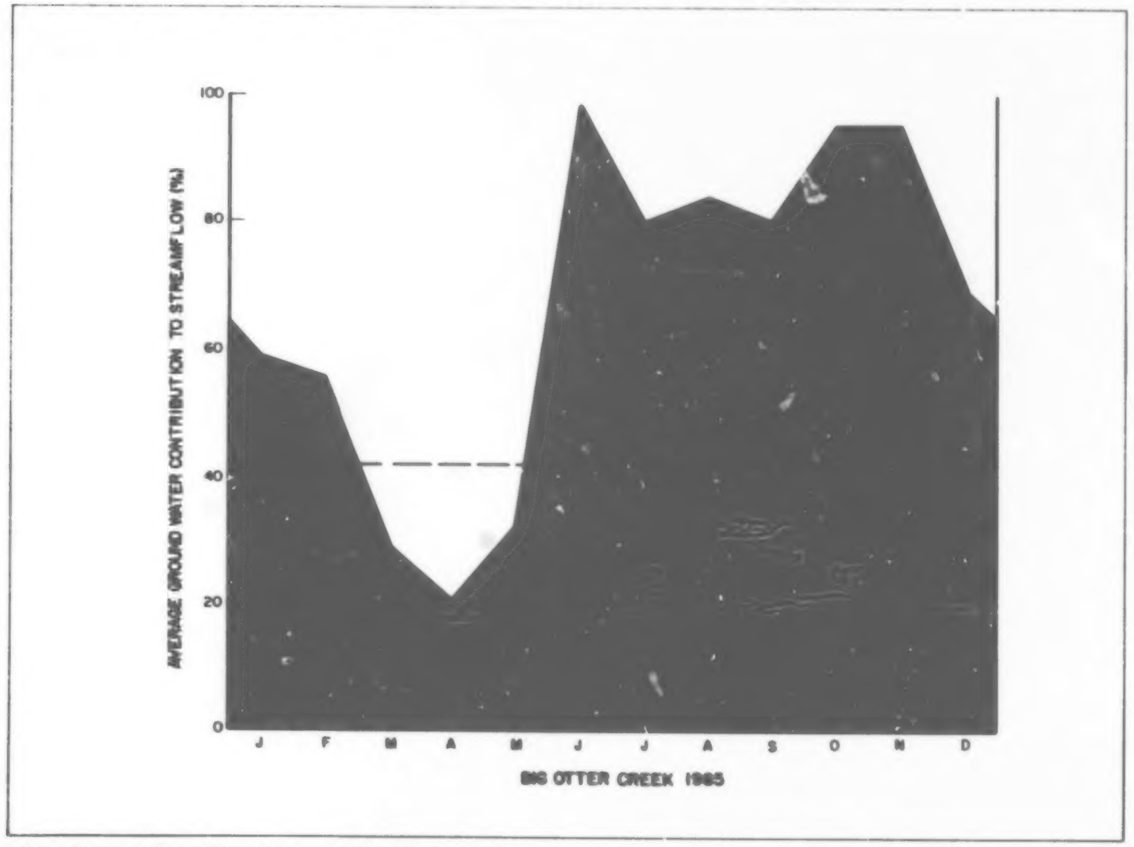
Over most of Ontario, as shown on the map opposite, the mean annual contribution of ground water to streamflow is less than 20 per cent. This is due to the predominance of silt and clay or poorly fractured bedrock at the ground surface. In areas where sand and gravel are found at the surface, the annual contribution of ground water to local streams can be up to 60 per cent of the mean annual streamflow, while in some areas contributions close to 100 per cent are common during summer months.

On a seasonal basis, the percentage contribution of ground water to streamflow is highly variable, although the actual rate of ground water discharge may be relatively uniform. Figure 17.1 illustrates this variation for Big Otter Creek, which drains predominantly a sand plain area in southern Ontario. During the spring runoff, the percentage contribution drops to as low as 20 per cent, while during the summer, ground water contributes over 95 per cent of the streamflow. On an annual basis, 42 per cent of the mean annual streamflow in Big Otter Creek is obtained from ground water.

It needs to be stressed that there is a delicate natural balance between the amount of recharge of ground water from precipitation and the discharge of some of that ground water to streams. Man-made alterations can, and often do, affect that balance, with the result that ground water discharge to streams is changed. While certain alterations can increase the discharge, more commonly shifts in the balance result in a decrease of ground water discharge. In large streams this effect may not be noticeable, but the effects on smaller streams can lead to serious conflicts in downstream water use. Consequently, it is important to consider ground water not as a solitary source of water to be developed or mined indiscriminantly, but rather as an intimate link to surface water in the context of the hydrologic cycle.

References listed on page 48

- 17.1 to 17.8 inclusive



17.1 *Ground Water Contribution to Big Otter Creek*

ANNUAL GROUND WATER CONTRIBUTION TO LOCAL STREAMFLOW

▨ 0 - 20 %

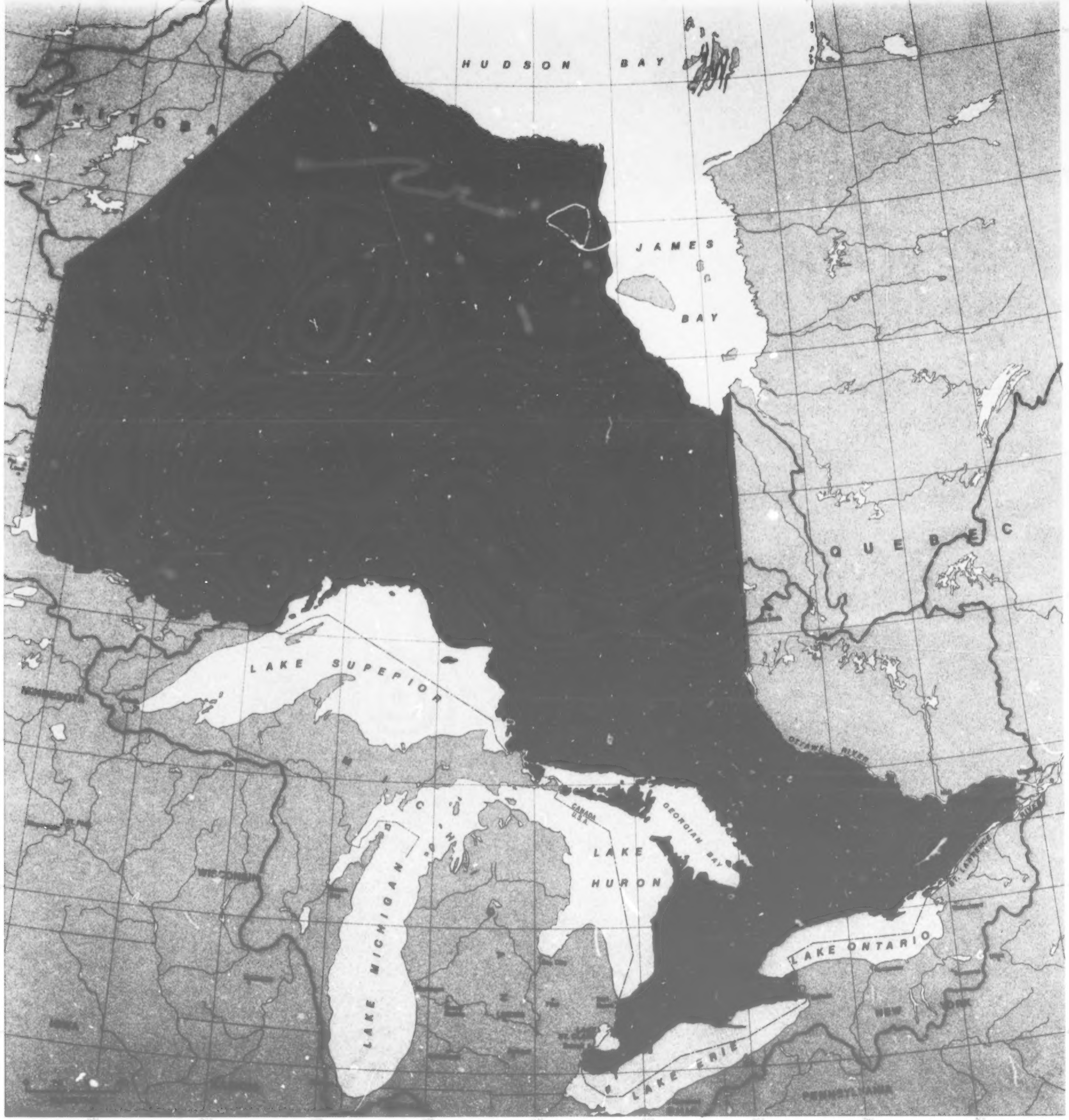
▨ 20 - 40 %

▨ 40 - 60 %

✱ LOCATION OF BIG OTTER CREEK

— PRIMARY DRAINAGE BASIN BOUNDARY

— SECONDARY DRAINAGE BASIN BOUNDARY


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
OTTAWA RIVER
ST. LAWRENCE RIVER
LAKE SUPERIOR
CANADA
U.S.A.
GEORGIAN BAY
LAKE HURON
LAKE MICHIGAN
MICHIGAN
LAKE ONTARIO
LAKE ERIE
NEW YORK
PENNSYLVANIA

List of References

13.1 Douglas, R.J.W., 1968
Geology & Economic Minerals of Canada
Geology Survey of Canada
Department of Energy, Mines and Resources, 5th Edition
Economic Geology Report No. 2,
Maps 1250A–11257A.

13.2 Freeman, E.B., ed., 1978
Geological Highway Map,
Southern Ontario
Ontario Geological Survey, Map 2418,
Scale 1:800 000

13.3 Hewitt, D.F., 1972
Paleozoic Geology of Southern Ontario
Ontario Division of Mines, Ministry of Natural Resources
GR 105, Map 2254, Scale 1 in. to 16 mi

13.4 Ontario Geological Survey, 1980
Geological Highway Map,
Northern Ontario
Ontario Geological Survey, Map 2440,
Scale 1:1 600 000.

13.5 Sanford, B.V., 1969
Geology Toronto-Windsor Area
Geological Survey of Canada, Department of Energy Mines and Resources, Map 1263A, Scale 1:250 000.

13.6 White, O.L., 1983
Geology of Ontario
19th Forum on the Geology of Industry Minerals, Proceedings, Ontario Geological Survey Miscellaneous Paper 114, 1983, 8 p

13.7 Northern Ontario Engineering Geology, 1979 – 1983
Terrain Study Series
Ontario Geological Survey

14.1 Brown, I.C., 1967
Ground Water in Canada
Geological Survey of Canada
Department of Energy, Mines and Resources, Economic Geology Report No. 24.

14.2 Haefeli, C.J., 1972
Ground Water Inflow into Lake Ontario from the Canadian Side
Inland Water Branch Environment Canada, Scientific Series No. 9

14.3 Ontario Ministry of the Environment, 1973
Lake Ontario Drainage Basin Overburden Well Yields
Water Quality Management Branch Ontario Ministry of the Environment, Map 5926-2,
Scale 1:500 000

14.4 Ontario Water Resources Commission, 1970
Lake Ontario Drainage Basin Bedrock Well Yields Division of Water Resources, Ontario Water Resources Commission, Map 5926-1, Scale 1:500 000

15.1 Boissoneau, A.N., 1965
Algoma-Cochrane Surficial Geology
Ontario Department of Lands and Forests Map S365, Scale 1:506 880

15.2 Ontario Department of Lands and Forests, 1965
Algoma, Sudbury, Timiskaming and Nipissing Surficial Geology
Map 2465, Scale 1:506 880

15.3 Chapman, L.J. and Putnam, D.F., 1973
The Physiography of Southern Ontario
2nd Edition, University of Toronto Press
Accompanied by Maps 2224-2228,
Scale 1:253 400

15.4 Ontario Ministry of the Environment, Water Resources Branch, 1969 – 1982
Water Resources Report Series No. 1-15

15.5 Zoltai, S.C., 1965
Kenora-Rainy River Surficial Geology
Ontario Department of Lands and Forests, Map S165, Scale 1:506 880

15.6 Ontario Department of Lands and Forests, 1965
Thunder Bay Surficial Geology, Map S265,
Scale 1:506 880

16.1 See 14.1 above.

16.2 Freeze, A.R. and Cherry, J.A., 1979
Ground Water
Prentice-Hall

16.3 See 14.2 above.

16.4 See 14.3 above.

16.5 See 15.4 above.

16.6 Ontario Ministry of the Environment, 1969 – 1978
Water Resources Map Series

16.7 Sibul, U.D., Walmsley, D., and Szudy, R., 1980
Ground Water Resources in the Grand River Basin: Grand River Basin Water Management Study, Grand River
Implementation Committee
Technical Report Series,
Report No. 10

16.8 Federation of Associations on the Canadian Environment, 1975
National Inventory of Municipal Waterworks and Waste Water Systems in Canada
Federation of Associations on the Canadian Environment

17.1 Eddie, J.D., 1973 – 1979
Low Flow Characteristics of Streams
Hydrogeologic Data Section, Water Quality Management Branch Ontario Ministry of the Environment, Maps 3005:1 – 4
Scales 1:250 000 to 1:800 000

17.2 Eddie, J.D., unpublished
A General Classification of Streamflows in Southern Ontario
Hydrology and Monitoring Section Water Resources Branch
Ontario Ministry of Environment

17.3 Environment Canada, 1981
Surface Water Data References Index CANADA 1981
Inland Waters Directorate, Water Resources Branch, Water Survey of Canada.

17.4 Water Survey of Canada, 1980
Historical Streamflow Summary ONTARIO to 1979
Inland Waters Directorate, Water Resources Branch

17.5 See 15.4 above.

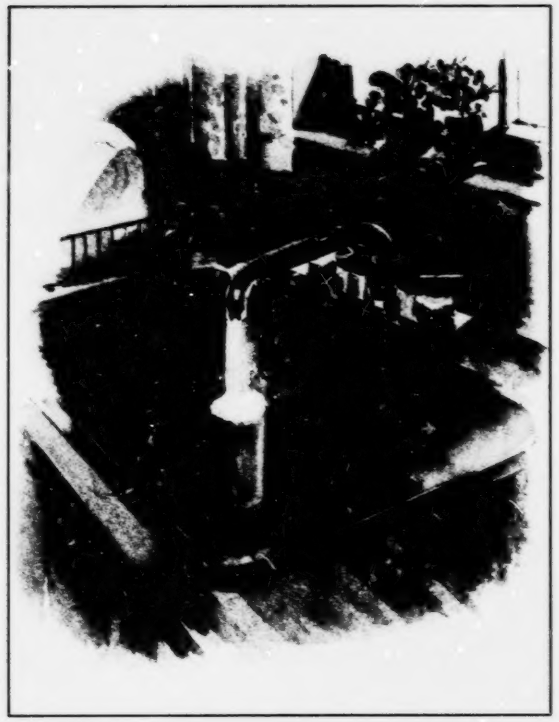
17.6 See 16.6 above.

17.7 See 16.7 above.

17.8 Swam, D.R. and Condie, R., 1983
Computation of the Base Flow Index Program BFINDEX
Inland Waters Directorate, Water Resources Branch, Environment

General Ontario Waste Management Corporation, 1983
Hydrogeologic Inventory for Waste Facilities Development, Southern Ontario Map, Figure 1,
Scale 1:1 000 000

WATER USE



Introduction

In Ontario's urban areas, each person uses about 395 L (87 imp gal) of water per day for domestic needs. Ten litres (2.2 imp gal) of water is used in the production of 1 L of gasoline and 250 000 L (55 000 imp gal) is used in the production of 1 tonne (2,200 lb) of steel. Surface and ground water resources are, therefore, very significant to the economy of Ontario.

In the discussion of water use, a distinction is made between two main types of water use, namely "withdrawal" use which includes consumptive uses and "in situ" use. "Withdrawal" use refers to water transferral from a surface or ground water source to a location where it is used, after which it is returned to a surface or ground water body. A portion of the water is consumed and is not available for subsequent reuse. In some publications this type of use is identified as "consumptive" use. "In situ" use refers to the use of water within or close to its natural boundaries. In this type of use, the amount of water consumed is negligible.

"Withdrawal" water for domestic and industrial uses in urban areas is provided by public (municipal) water supply systems. Private water supply systems are used in rural areas to provide "withdrawal" water for domestic and farm needs, livestock watering and crop irrigation. Major industries in the manufacturing and mining sectors, as well as fossil fuel and nuclear power plants for the thermal generation of electricity, require substantial volumes of "withdrawal" water which are also most often supplied through private systems.

In Ontario, the portion of the "withdrawal" water that is consumed is small but significant. Irrigated agriculture and major industries are the primary consumers of water in the province.

Hydroelectic power generation utilizes "in situ" water flows and differences in surface water levels. Commercial shipping is an "in situ" use of water which depends on natural and artificial water routes with suitable depths of water. "In situ" recreational uses of water resources include open water swimming and diving, canoeing and pleasure boating, with access and facilities provided by both public and private sectors. Water is also the natural environmental habitat for fish and wildlife, and both commercial and sport fishing represent an "in situ" use of water.

The return of wastewater to water bodies, following a "withdrawal" water use, represents an "in situ" use of water bodies for conveyance, dilution and treatment of wastes.

Three key aspects of water use in the province are described in this section. Municipal water supply and other withdrawal water uses are discussed in some detail on pages 52 to 59. The importance of Ontario's river basins for hydroelectric power generation and the very significant national and international use of Ontario's Great Lakes water transportation system for commercial shipping are discussed on pages 60 to 63. Tourism and the recreational and environmental use of water are presented on pages 64 to 69.

A concluding discussion on future use of water is presented on page 70.

Numerous sources of information have been used in the preparation of this section. The corresponding references are listed on page 71.

18 – Municipal Water Supply

Ontario's total population is about 8.6 million (1981 figures). Of this total about 7.5 million, or 87 per cent, is serviced by a municipal water supply system. This is about 4 per cent higher than the Canadian average. About 4.9 million, or 69 per cent, of this municipally-served population resides in the 10 major urban centres. These major urban centres, each with a population greater than 100 000, are each served by an integrated municipal water supply system. The Toronto/Mississauga urban centre accounts for 2.8 million, or 56 per cent, of the served population in the 10 major urban centres.

Average daily municipal water use in 1981 has been shown separately on the map opposite for these major urban centres, at the appropriate locations. Average daily water use for secondary urban areas is shown opposite by drainage basin, excluding the major urban centres.

The following table gives a summary of average municipal water use in Ontario in millions of cubic metres per day (Mm³/d), including the division between surface water sources and ground water sources.

	Municipal Water Use (Mm³/d)		
Location	Surface Water Sources	Ground Water Sources	Total All Sources
Major urban centres	2.885	0.084	2.969
Secondary urban areas	1.123	0.394	1.517
Total All Urban Areas	4.008	0.478	4.486

The total municipal water use of 4.486 Mm³/d is equivalent to an annual water depth of 1.5 mm over the province and represents about 0.5 per cent of the mean annual runoff for the province.

Ground water sources contribute only 3 per cent of the total water supply to the 10 major urban centres. About 92 per cent of this ground water supply is used in the Kitchener/Waterloo urban area, which depends entirely on ground water for its municipal supply. Use of ground water in the other major urban centres is minimal. However, in the secondary urban areas, ground water sources provide an average of 26 per cent of the total water supply. There is generally a fairly heavy dependence on ground water in southern Ontario, and in the Timmins area of Northern Ontario.

Municipal water supplies are used to meet both domestic (residential, commercial, and institutional) and industrial water needs.

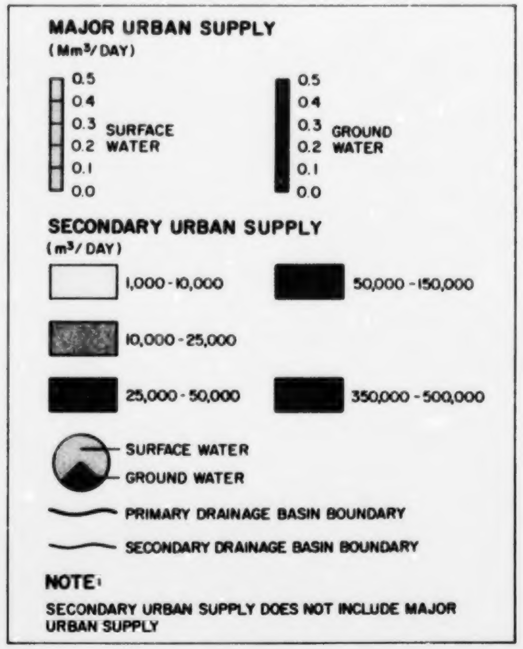
Water requirements for domestic needs are generally proportional to the served population. Appropriate average water use per person data for the various Ontario drainage basins have been derived from previous studies to develop estimates of domestic water use. These values range from 340 L/person/d in the Lake Erie basin to about 740 L/person/d in the Nelson River basin.

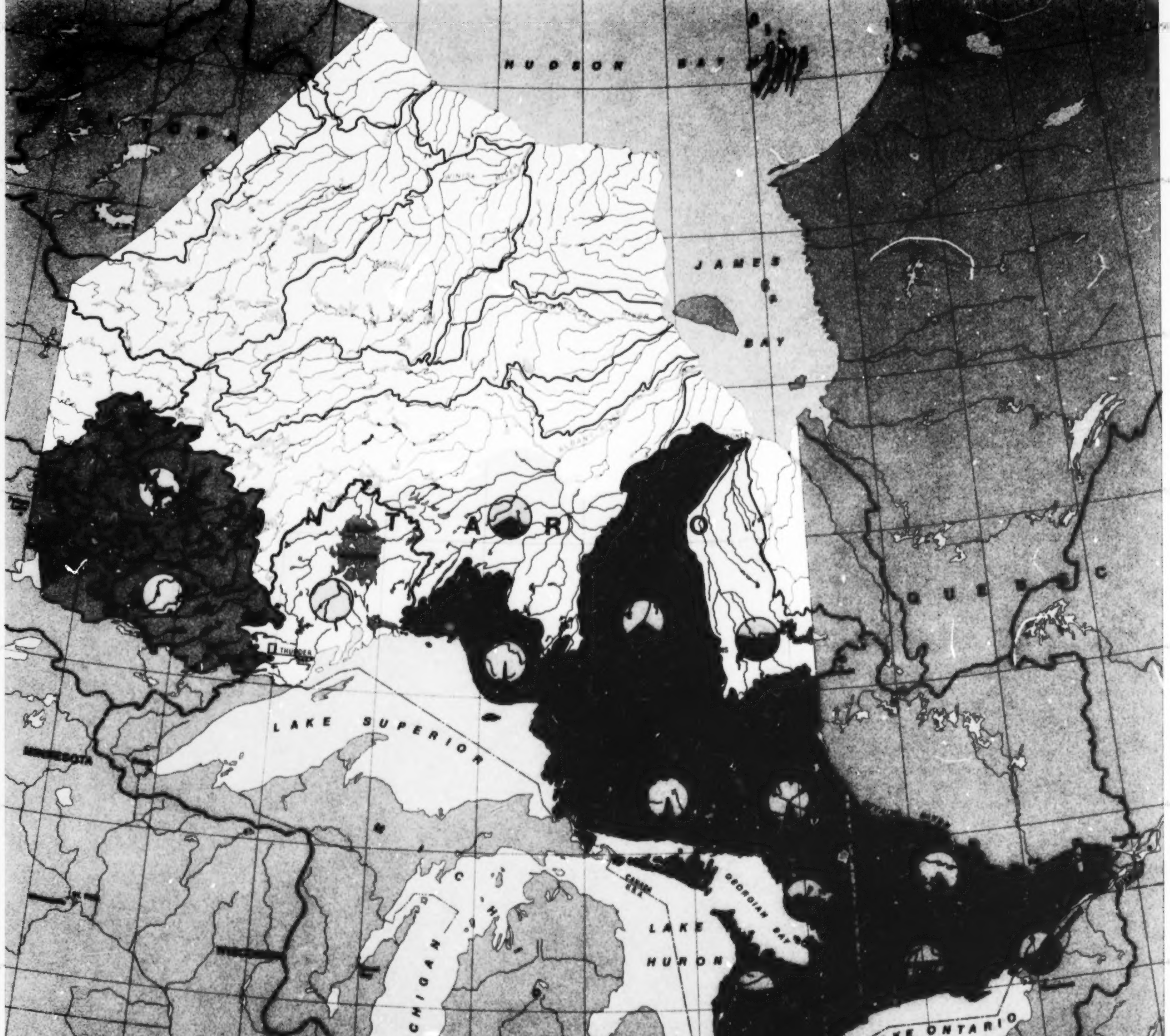
Estimates of the industrial water use component of municipal water supplies have been obtained by subtracting the estimates of domestic water use from the total municipal water use.

Both the domestic and industrial components of municipal water use, estimated as described above, are presented in conjunction with other "withdrawal" water uses on pages 56 to 59.

References listed on page 71:

- 18.1 to 18.4 inclusive


MAJOR URBAN SUPPLY
(Mm³/ DAY)
0.5
0.4
0.3
0.2
0.1
0.0
SURFACE WATER
0.5
0.4
0.3
0.2
0.1
0.0
GROUND WATER
SECONDARY URBAN SUPPLY
(m³/ DAY)
1,000 - 10,000
50,000 - 150,000
10,000 - 25,000
25,000 - 50,000
350,000 - 500,000
SURFACE WATER
GROUND WATER
PRIMARY DRAINAGE BASIN BOUNDARY
SECONDARY DRAINAGE BASIN BOUNDARY
NOTE:
SECONDARY URBAN SUPPLY DOES NOT INCLUDE MAJOR URBAN SUPPLY


HUDSON BAY
JAMES BAY
ONTARIO
QUEBEC
LAKE SUPERIOR
MINNESOTA
MICHIGAN
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE
92°
90°
88°
86°
84°
82°
80°
78°
76°

19 – Municipal Treated Wastewater

After being used for domestic and industrial purposes, municipal water is returned to natural water bodies, following treatment at municipal wastewater treatment plants. The water bodies receiving wastewater are streams, rivers or lakes.

In Ontario, municipal wastewater treatment is provided for about 85 per cent of the municipally-served population. This is substantially higher than the equivalent Canadian national average of 58 per cent.

The treatment given to the wastewater at municipal plants varies from location to location across the province, and the natural water bodies themselves are able to provide some physical, chemical and biological treatment.

An indication of the usage of river and lake flows for dilution and conveyance of treated wastewater has been given on the map opposite by expressing cumulative municipal treated wastewater return flow as a percentage of mean annual flow at specific locations. (Wastewater from private industrial systems is not included.) This has been done for downstream locations on all rivers in Ontario which have municipal wastewater return flows greater than 0.5 per cent of the mean annual river flow. It has also been done separately for the key gauging locations along Ontario's southern and eastern boundary waters--The Great Lakes system and the Ottawa River. In this latter case, the cumulative municipal treated wastewater from Ontario only has been considered. Drainage basins with wastewater flow components greater than 0.5 per cent are also identified.

If mean seasonal river flows were used instead of mean annual flows the wastewater flow component percentage would change accordingly.

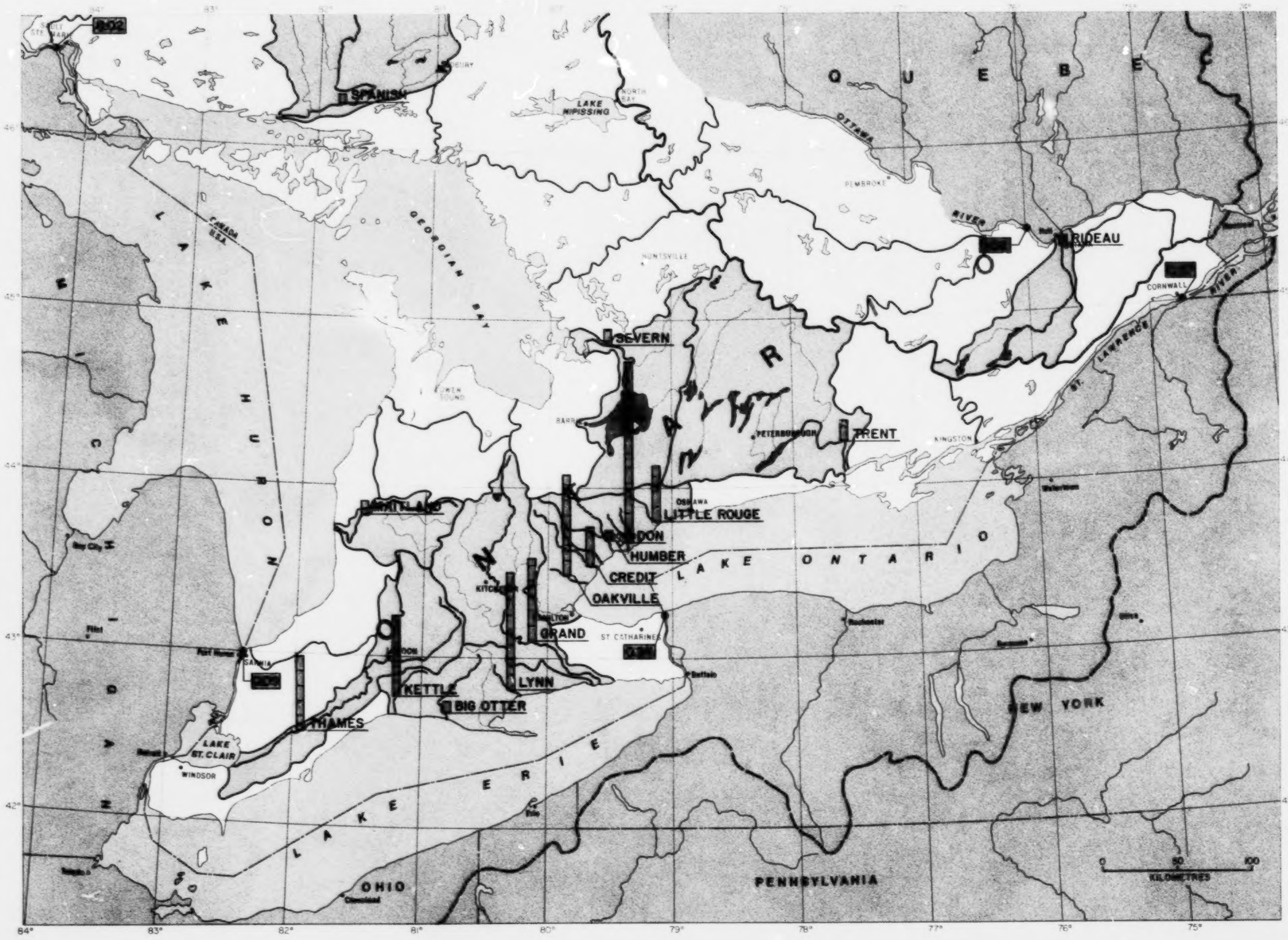
Many of the rivers in the Lake Ontario/Lake Erie basins are important in this respect, compared to the rest of the region. Toronto's Don River has the greatest treated wastewater flow component, about 12 per cent. By comparison, rivers in Northern Ontario have negligible treated wastewater flow components.

Many municipal plants discharge treated wastewater directly to the Great Lakes and, of course, the rivers in the corresponding drainage basins discharge there also. The Great Lakes, therefore, receive the full municipal treated wastewater discharge. It is significant to note the increasing treated wastewater flow component from upstream to downstream (west to east) through the Great Lakes system. Almost 0.6 per cent of the mean annual flow leaving Ontario through the St. Lawrence River is treated wastewater flow returned by municipal treatment plants in Ontario.

References listed on page 71:

- 19.1 to 19.3 inclusive

▒	BASINS WITH MUNICIPAL FLOW COMPONENT OF RIVER DISCHARGE GREATER THAN 0.5 % IN ONE OR MORE RIVERS
▮ 3 2 1 0	AVERAGE MUNICIPAL WASTEWATER FLOW COMPONENT OF TOTAL RIVER DISCHARGE (%)
■	AVERAGE MUNICIPAL WASTEWATER FLOW COMPONENT OF TOTAL BOUNDARY LAKE AND RIVER DISCHARGE (%) (ONTARIO MUNICIPAL WASTEWATER ONLY)
∼	PRIMARY DRAINAGE BASIN BOUNDARY
∼	SECONDARY DRAINAGE BASIN BOUNDARY



SPANISH
LAKE NIPISSING
NORTH BAY
GEORGIAN BAY
LAKE HURON
CANADA
U.S.A.
MICHIGAN
Q U E B E C
OTTAWA RIVER
PEMBROKE
RIDEAU
HUNTSVILLE
CORNWALL
ST. LAWRENCE RIVER
O N T A R I O
SEVERN
OWEN SOUND
BARRIE
PETERBOROUGH
TRENT
KINGSTON
OSHAWA
LITTLE ROUGE
MAITLAND
DON
HUMBER
CREDIT
OAKVILLE
LAKE ONTARIO
KITCHENER
HAMILTON
GRAND
ST CATHARINES
Buffalo
Rochester
Syracuse
Utica
Watertown
Port Huron
SARNIA
LONDON
KETTLE
LYNN
BIG OTTER
THAMES
LAKE ST. CLAIR
Detroit
WINDSOR
Bay City
Flint
LAKE ERIE
Erie
Toledo
Cleveland
OHIO
PENNSYLVANIA
NEW YORK
0 50 100
KILOMETRES
84°
83°
82°
81°
80°
79°
78°
77°
76°
75°
46°
45°
44°
43°
42°

20 – Total Withdrawals and Consumption

In addition to municipal water use, there are 3 further classifications of "withdrawal" water use, which are

- rural, which covers the use of water for domestic, livestock and irrigation purposes in nonurban areas
- major industrial, which includes the use of water for manufacturing and mining processes not served by municipal systems
- thermal power, which covers water use for several purposes, including cooling, at both fossil fuel and nuclear generating stations.

Ontario's average rural domestic water use is 160 L/person/d from published studies. Information on water use for livestock and irrigation was similarly available, enabling a complete estimate to be made of all rural water use by drainage basins in the base year (1981).

A similar procedure was followed to develop estimates of total water use by all industries. These estimates were reduced by the municipal water supply to industry, already discussed on page 52. The resulting water use estimate is the major industrial water use, which has both manufacturing and mining components. Of the total water used by industry in Ontario, only 9 per cent is supplied by the municipal systems, and it has been assumed that all of this is used in the manufacturing sector.

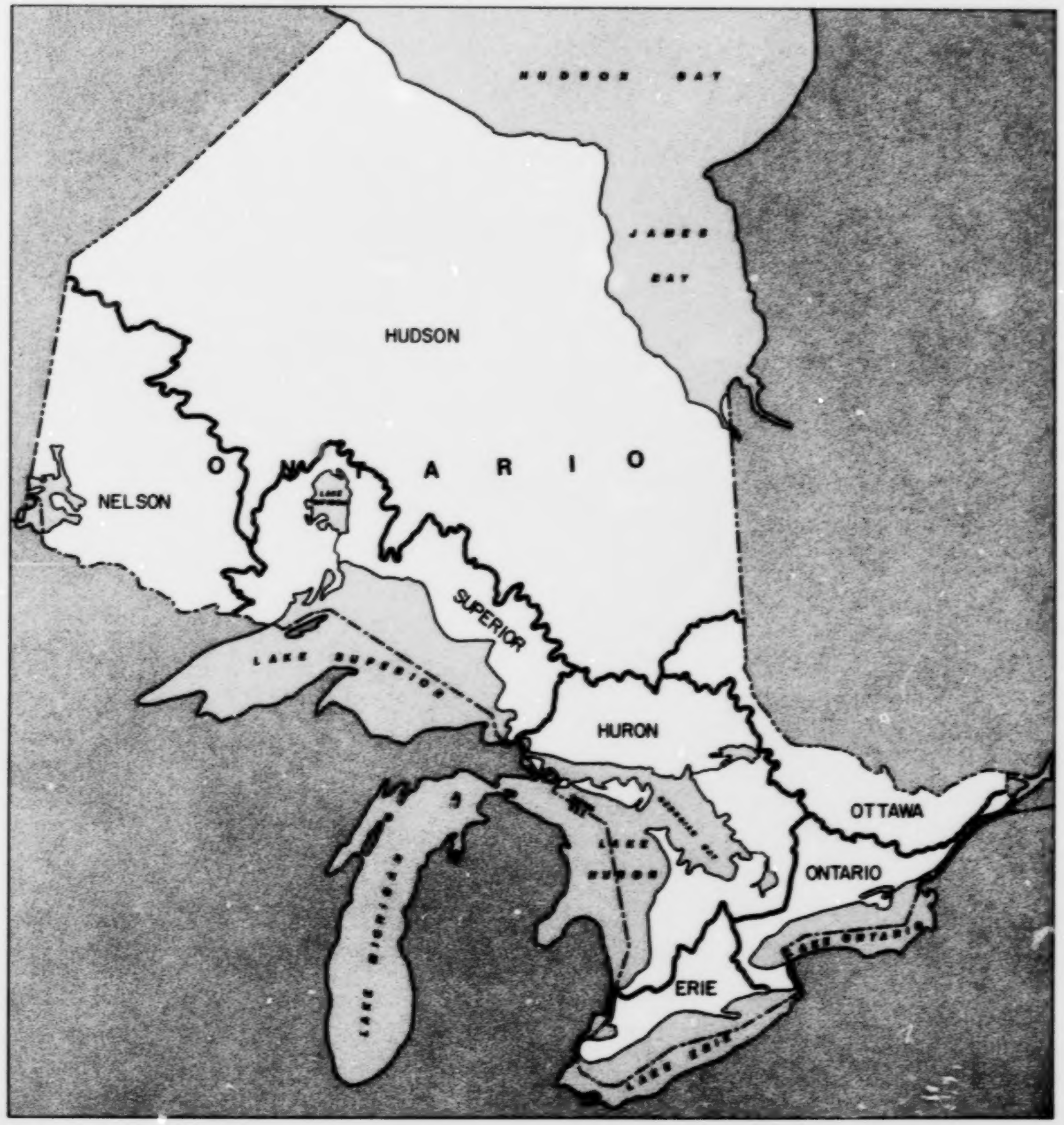
In the case of water use for thermal electric power generation, information from the published studies was supplemented by updated information on power generation to determine the split between conventional fossil fuel plants and nuclear plants by drainage basin. This split is important due to the significantly greater use of water by nuclear plants compared with conventional thermal plants, as shown for 2 major drainage basins in the following table.

	Proportion of Energy Production and Water Use (Per Cent)			
	Lake Huron Drainage Basin		Lake Ontario Drainage Basin	
	Conventional Plants	Nuclear Plants	Conventional Plants	Nuclear Plants
Energy production	19	81	57	43
Water use	12	88	45	55

Figure 20.1 identifies the major basins in Ontario which are used in discussing water use. The Lakes Superior, Huron, Erie and Ontario basins are treated separately in discussions of water use.

The quantities of water used in each major basin for the 4 classifications of "withdrawal" water use are shown in Figure 20.2 and the relative importance of the various water users within each classification is shown in Figure 20.3. Municipal and rural water uses have been shown separately from major industrial and thermal power water uses since the magnitudes of water use quantities are very different.

Municipal water use in the Lake Ontario drainage basin is much greater than in the other basins because of the several major urban centres located there. The Toronto/Mississauga area alone uses 1.663 Mm^3/d. The industrial component of municipal water use is very substantial in the Lakes Ontario, Erie and Superior basins. Rural water use is greatest in the Lake Erie basin due to extensive irrigation of crops.

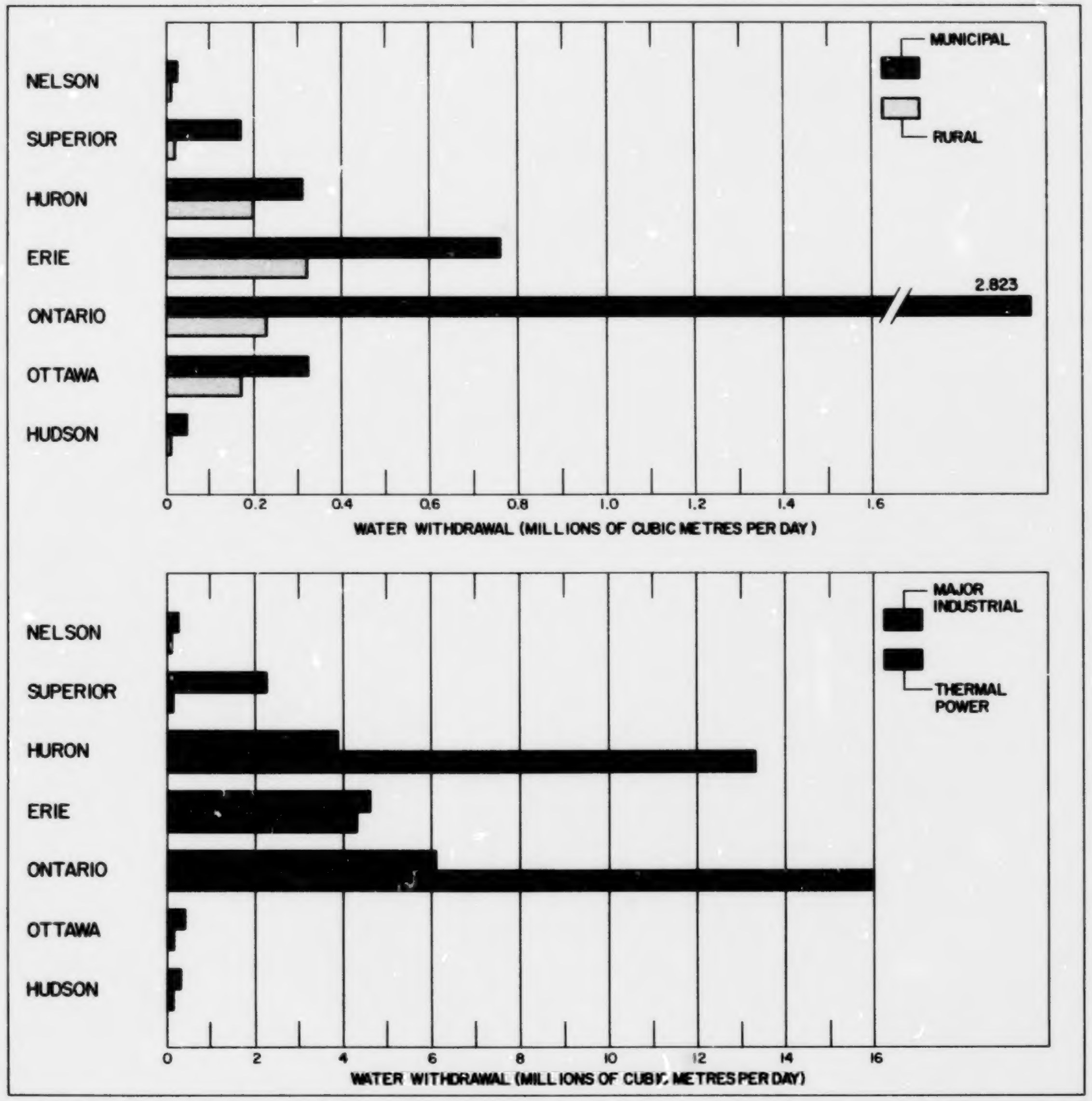


20.1 *Drainage Basins*

Major industrial water use is substantial in all of the Great Lakes drainage basins, with the heaviest use occurring in the Lake Ontario basin. The manufacturing sector dominates industrial water use. The greatest water use overall is for thermal power generation in the Lake Ontario and Lake Huron basins where the province's 2 major nuclear generating complexes are located.

Each "withdrawal" water use discussed above results in some water being consumed. A consumption factor (ratio of consumed water to total withdrawal) has been obtained for each "withdrawal" water use from published studies. This factor ranges between 50 and 100 per cent in the case of rural water uses, and is about 15 per cent for domestic water use in urban areas. For other "withdrawal" water uses, the consumption factor is less than 5 per cent.

Estimates of the water quantities consumed in each drainage basin were derived by applying the consumption factors to the water use estimates. They are depicted in Figure 20.3 as proportions of total withdrawal.



20.2 Major Water Withdrawals by Drainage Basin

The following table summarizes the total "withdrawal" water use in Ontario and the water consumption in millions of cubic metres per day (Mm^3/d). Consumption factors are also shown.

"Withdrawal"	Water Use (Mm^3/d)		Consumption
Water Use	Withdrawal	Consumption	Factor (Per Cent)
Municipal	4.486	0.489	11
Rural	0.965	0.754	78
Major industrial	17.960	0.712	4
Thermal power	33.636	0.252	less than 1
TOTAL	57.047	2.207	4

The total "withdrawal" water use of 57.047 Mm^3/d represents about 6.6 per cent of the mean annual runoff for the province. It should be noted that the municipal use shown above includes supplies provided to industries.

Information is not readily available to compare current "withdrawal" water uses in Ontario with those in the rest of Canada, but some approximate indications are as follows.

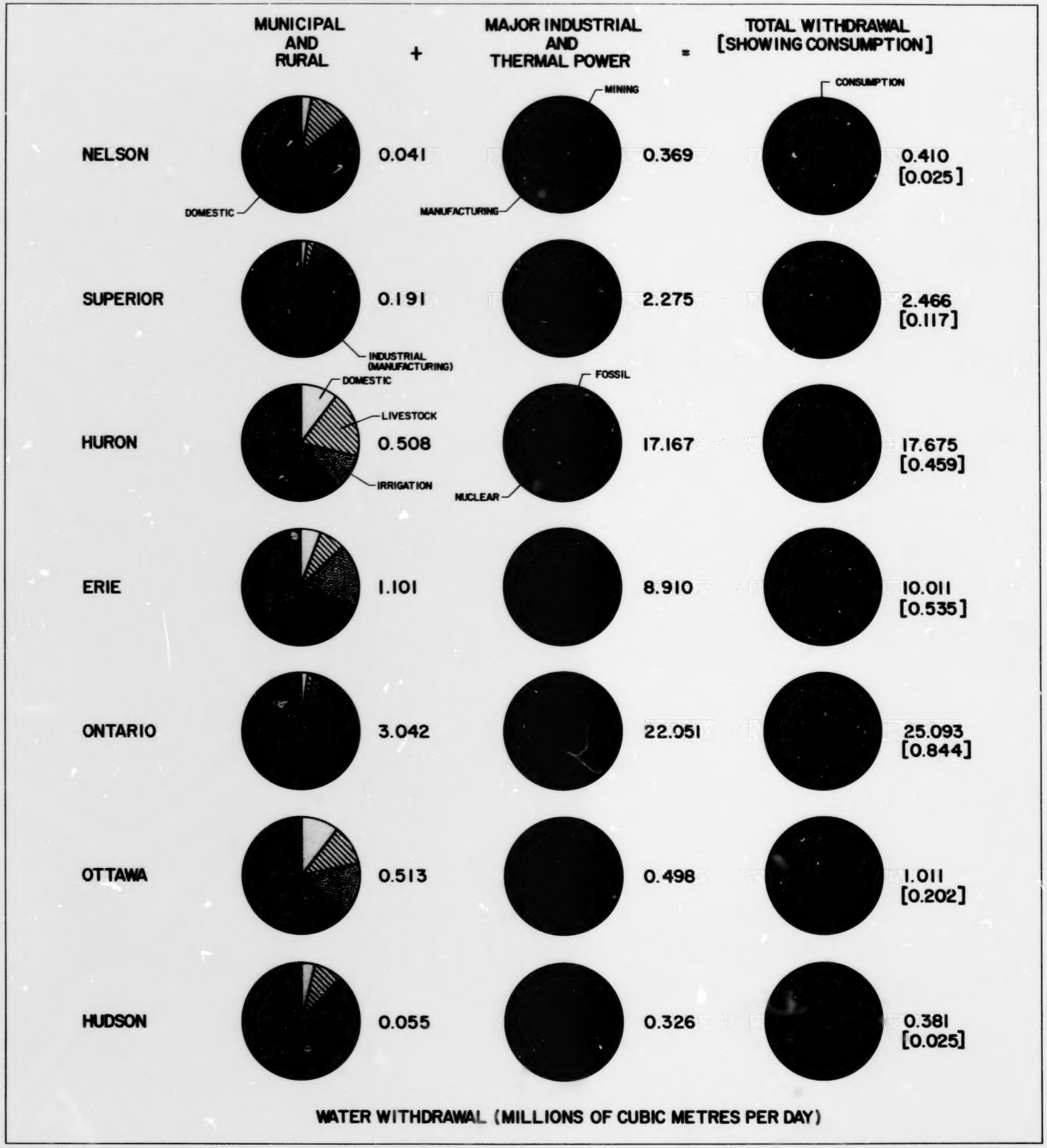
- Ontario's municipal water use is about 35 per cent of the total municipal water use in Canada. Among the other provinces only Quebec has a comparable percentage.

- Rural domestic water use in Ontario is about 30 per cent of the Canadian total. However, overall rural water use is only 10 per cent of the Canadian total compared to almost 60 per cent for the prairie provinces and 25 per cent for British Columbia.

- Major industrial water use in Ontario is 45 per cent of the total in Canada. That is approximately twice the percentage for Quebec which is the next largest provincial user of water for industry.

- Ontario's water use for fossil fueled power generation is about 45 per cent of the Canadian total. This is followed by Alberta's 30 per cent. In nuclear fueled power generation Ontario virtually stands alone with 99 per cent of the Canadian water use. Overall water use for thermal power generation in Ontario is almost 70 per cent of the Canadian total.

- Total "withdrawal" water use in Ontario is estimated from the foregoing to be just over 50 per cent of the total "withdrawal" water use in Canada.



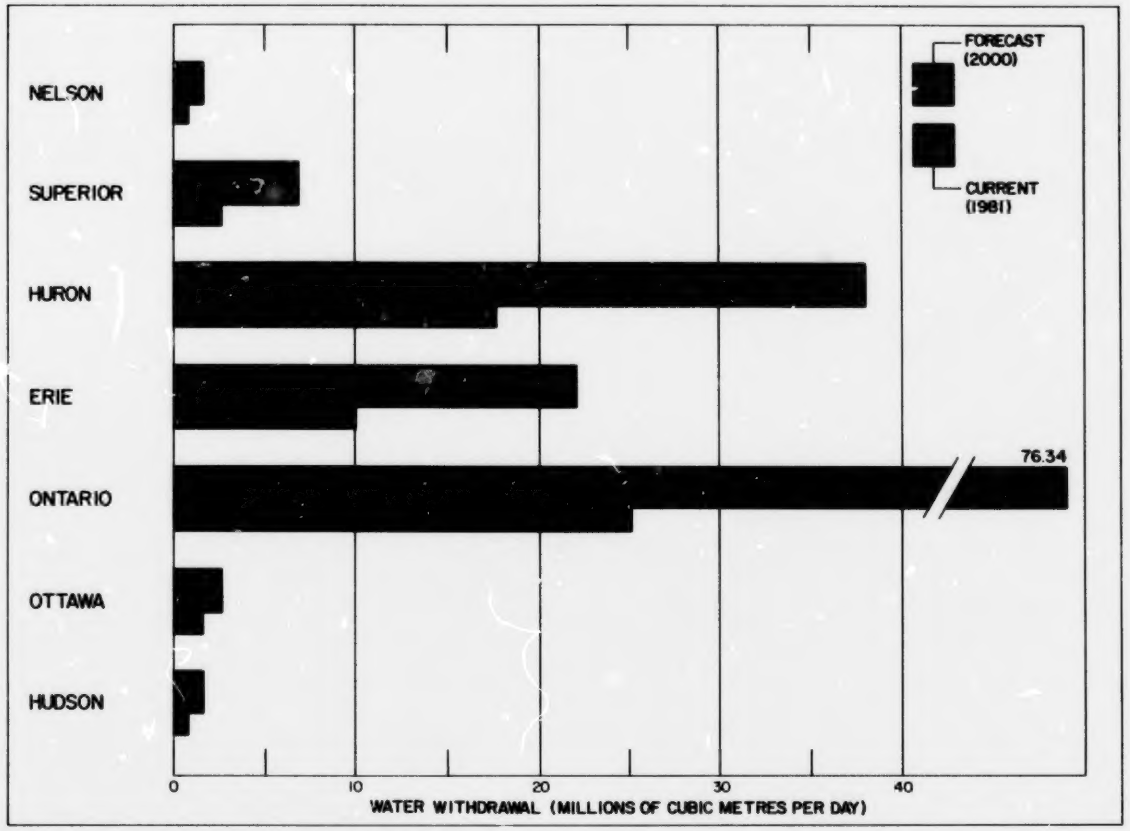
20.3 Breakdown of Major Water Withdrawals by Drainage Basin

Predictions of future "withdrawal" water use have been made in a published study of the entire Great Lakes region, which includes the major water use region of Ontario. This study was used as the basis for estimating "withdrawal" water use in the forecast year (2000).

Total "withdrawal" water use in each drainage basin for both the base year and the forecast year is shown in Figure 20.4. The greatest forecast withdrawal is for the Lake Ontario drainage basin and is about 3 times the current withdrawal. The forecast for total "withdrawal" use in Ontario by the year 2000 is 147.460 Mm^3/d, of which 3.981 Mm^3/d is forecast to be consumed. These values are, respectively, 2.6 and 1.8 times the 1981 values.

References listed on page 71:

— 20.1 to 20.8 inclusive



20.4 Total Water Withdrawals by Drainage Basin

21 – Hydroelectric Power

Hydroelectric power plants produce about 34 per cent of the total electric energy generated in Ontario. Unlike thermal electric power generation, which utilizes energy from fossil or nuclear fuels, hydroelectric power generation utilizes the energy of flowing water, combined with a difference in water level. Favourable conditions for hydroelectric power generation thus include large flows and the availability of large differences in water levels, usually exploited by means of dams. Such conditions exist in many of Ontario's river basins. Hydroelectric power generation is an "in situ" water use, even though evaporation from associated reservoirs can be greater than from the original natural land and water surfaces.

Power plant size can be described either in terms of installed capacity, which indicates the total potential of the plant to produce electricity, or in terms of energy production, which records actual annual production of electricity. Figure 21.1 shows the amount of hydroelectric power generation compared to fossil and nuclear fueled power generation in Ontario in 1982.

Ontario's power generation in relation to Canadian generation in each category for the same year is shown for comparison purposes in Figure 21.2.

From the point of view of water use by thermal electric power plants, annual energy production figures are the most relevant and form the basis of the estimates presented on pages 56 to 59. However, in the case of hydroelectric power plants, the installed capacity is an indication of the flow that can be utilized to produce power, and this is therefore the measure of power plant size used here. The map opposite shows the present distribution of installed hydroelectric generating capacity in Ontario, and the distribution of undeveloped capacity, by drainage basin.

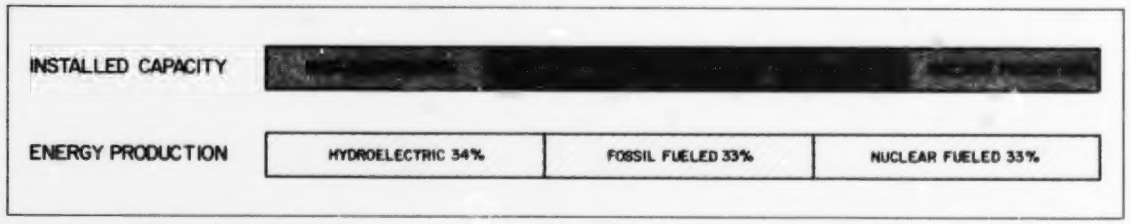
The generating capacity of plants located on provincial boundary waters is shown separately on the map opposite at the appropriate locations. This applies to plants on the St. Mary's, Niagara, St. Lawrence and Ottawa Rivers, although the St. Mary's River plant capacity was too small to be shown.

The total hydroelectric generating capacity of the province, both existing and undeveloped, is estimated to be about 21 000 Megawatts (MW). Up to the end of 1982, 7,174 MW of generating capacity had been installed--34 per cent of the total estimated capacity. It is also significant to note that over 50 per cent of the existing hydroelectric generating capacity of the province is installed on its boundary waters. If the total generating capacity were to be developed, this percentage would reduce to 30. Thus, any major flow changes in the boundary waters, particularly in the Great Lakes system, would have a significant impact on Ontario's hydroelectric generating capabilities.

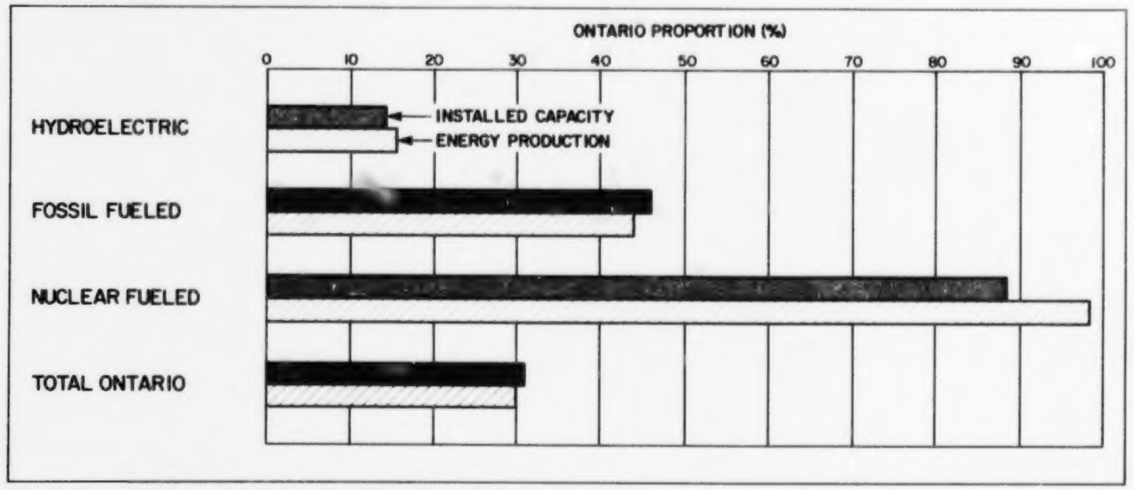
A major economic factor in the planning of future developments in the northern part of the province is the cost of transmission of electricity over long distances. Planning for future development of hydroelectric power generation in all areas would, of course, need to take account of other uses of the water resource, some of which are described on pages 62 to 69.

References listed on page 71:

- 21.1 to 21.3 inclusive



21.1 *Distribution of Power Generation*

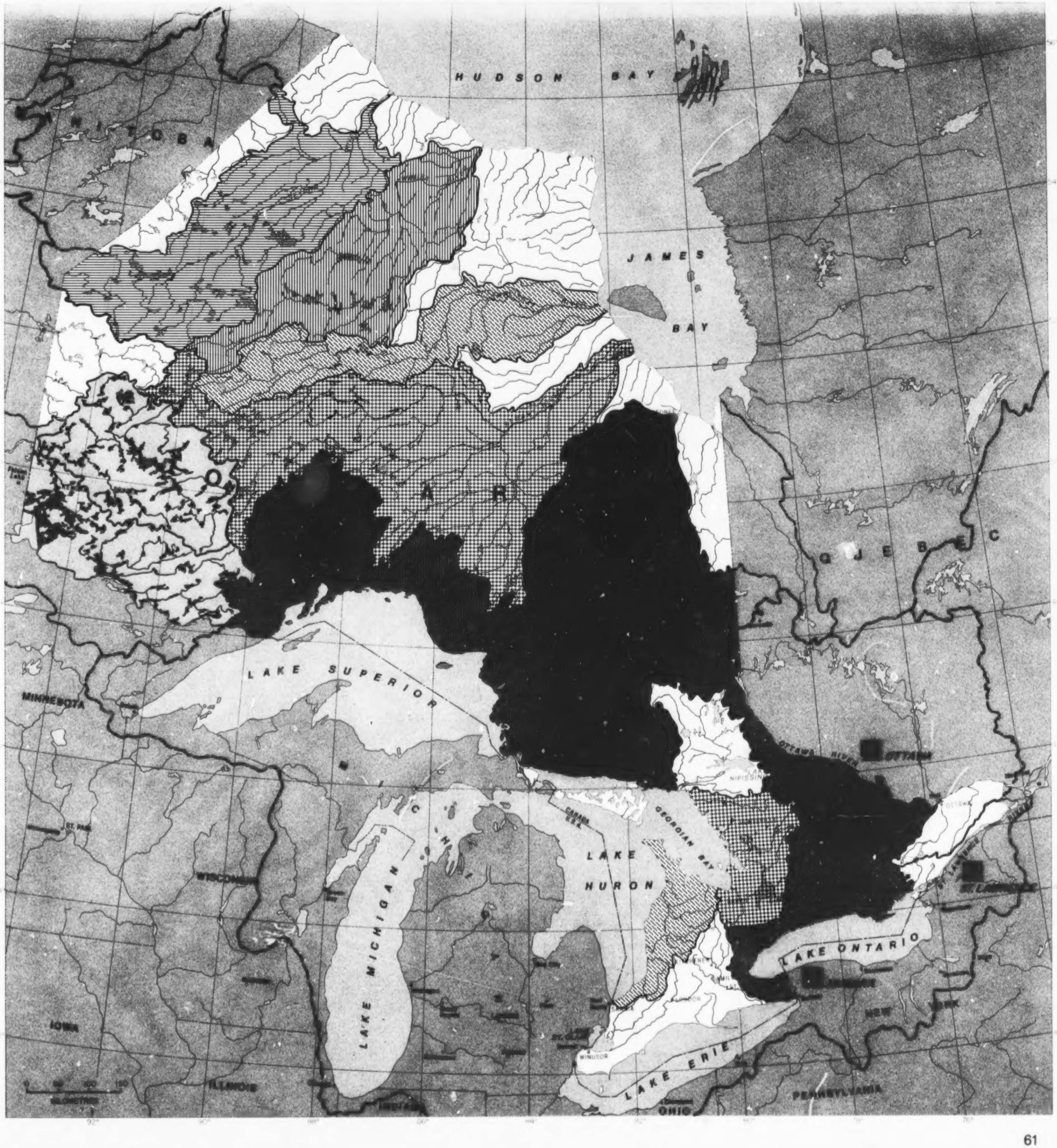


21.2 *Ontario's Proportion of Power Generation in Canada*

EXISTING CAPACITY (MW)		UNDEVELOPED CAPACITY (MW)	
☐	LESS THAN 100	☐	LESS THAN 100
░	100 - 200	▧	100 - 200
▒	200 - 400	▨	200 - 400
▓	400 - 800	▥	400 - 800
■	800 - 1600	▤	800 - 1600
■	GREATER THAN 1600	▦	GREATER THAN 1600

PRIMARY DRAINAGE BASIN BOUNDARY

SECONDARY DRAINAGE BASIN BOUNDARY


HUDSON BAY
MANITOBA
JAMES BAY
ONTARIO
QUEBEC
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
NIPISSING
OTTAWA RIVER
OTTAWA
LAKE ONTARIO
NEW YORK
LAKE ERIE
WINDSOR
LONDON
PENNSYLVANIA
OHIO
IOWA
ILLINOIS
KILOMETRES
0
50
100
150

22 – Commercial Shipping

Ontario's access to the world's foremost inland navigation system, the Great Lakes of North America, may be described as unique. Almost the entire northern shoreline of the system, from just south of Thunder Bay on Lake Superior, to just west of Montreal on the St. Lawrence River, falls within the boundaries of Ontario. The 3,200-km long Great Lakes system provides for water-based transportation of bulk cargo between the major agricultural regions in the western part of the continent and the major industrial centres of the east and overseas. Cargoes move nationally between Canadian or United States ports, and internationally between Canadian, United States and overseas ports.

A total of 49 ports on Ontario's Great Lakes shoreline handled 74.227 million tonnes of cargo in 1981. Fifty-three per cent of this cargo was shipped between Canadian ports while the remaining 47 per cent was shipped between Canadian and international ports. Of the total Canadian cargo handled, 62 per cent was loaded and 38 per cent was unloaded at Ontario ports; the equivalent figures for international cargo were 26 per cent loaded and 74 per cent unloaded at Ontario ports. Ontario, in terms of commercial water-based transportation of cargo on the Great Lakes system, is nationally a net exporter, while internationally it is a net importer.

In the same year, Ontario ports handled 28 per cent of the total Canadian domestic cargo and 16 per cent of the total Canadian international cargo. Of the total cargo handled at Canadian ports, 21 per cent was handled at Ontario ports.

Information on cargo handling at the ports was grouped on a lake basis. Ports located on the interconnecting waterways, such as the St. Clair and Detroit rivers, were included with those on the downstream (more eastern) lake. The cargo handling on a lake basis is shown in Figure 22.3 in sequence from west to east. In terms of total cargo handled, Lakes Superior, Erie and Ontario rank about equal in importance, with Lake Huron handling about half the cargo of any of the other Lakes. The split between loading and unloading within each lake gives some indication of the dominant flow of cargo from west to east.

Of the 49 ports considered, 13 ports handled cargo in excess of 1 million tonnes each, amounting overall to 89 per cent of the total cargo handled. The location of these ports is shown in Figure 22.2, and cargo handling at these ports is shown in Figure 22.4, in sequence from west to east. The unique importance of Thunder Bay as a loading port for predominantly agricultural (grain) cargoes to eastern and international destinations is clearly seen in contrast to the importance of Hamilton and Nanticoke as receiving ports for raw materials (iron ore and coal) used in heavy industry.

Variations in the levels of the Great Lakes can affect commercial shipping at critical locations by changing the scope of dredging operations and the permissible drafts and loading limits of vessels. Such critical locations include berthing wharves at ports and interconnecting waterways between lakes.

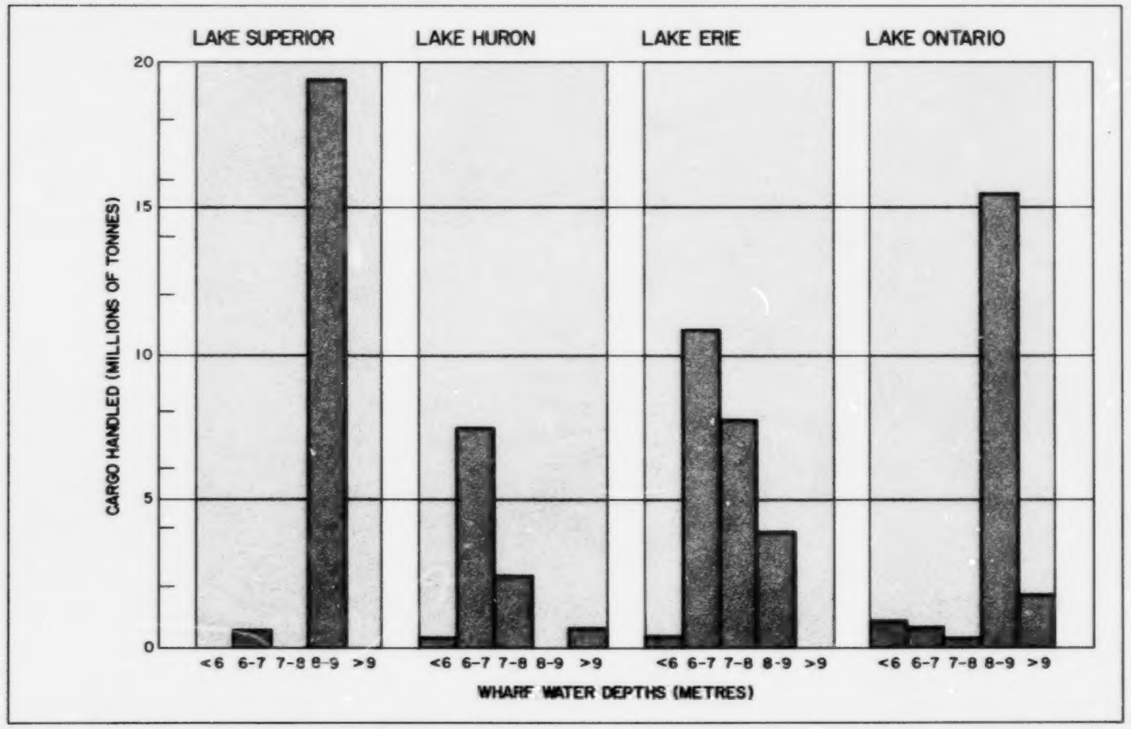
The ports on the Great Lakes have been grouped according to wharf depth, and the total cargo handled in each wharfage depth category has been shown for each lake in Figure 22.1. The relative importance of each range of wharf depth in each lake is clearly demonstrated.

The controlling navigation depth in all shipping channels is normally maintained at 8.2 m. Fifty-four per cent of the total cargo handling occurs at ports where wharf depths are maintained at this depth. The economic returns associated with shipping and handling of this cargo are therefore the most vulnerable to water level changes which will affect wharf depth, induce additional dredging costs and place limitations on vessel draft and loading.

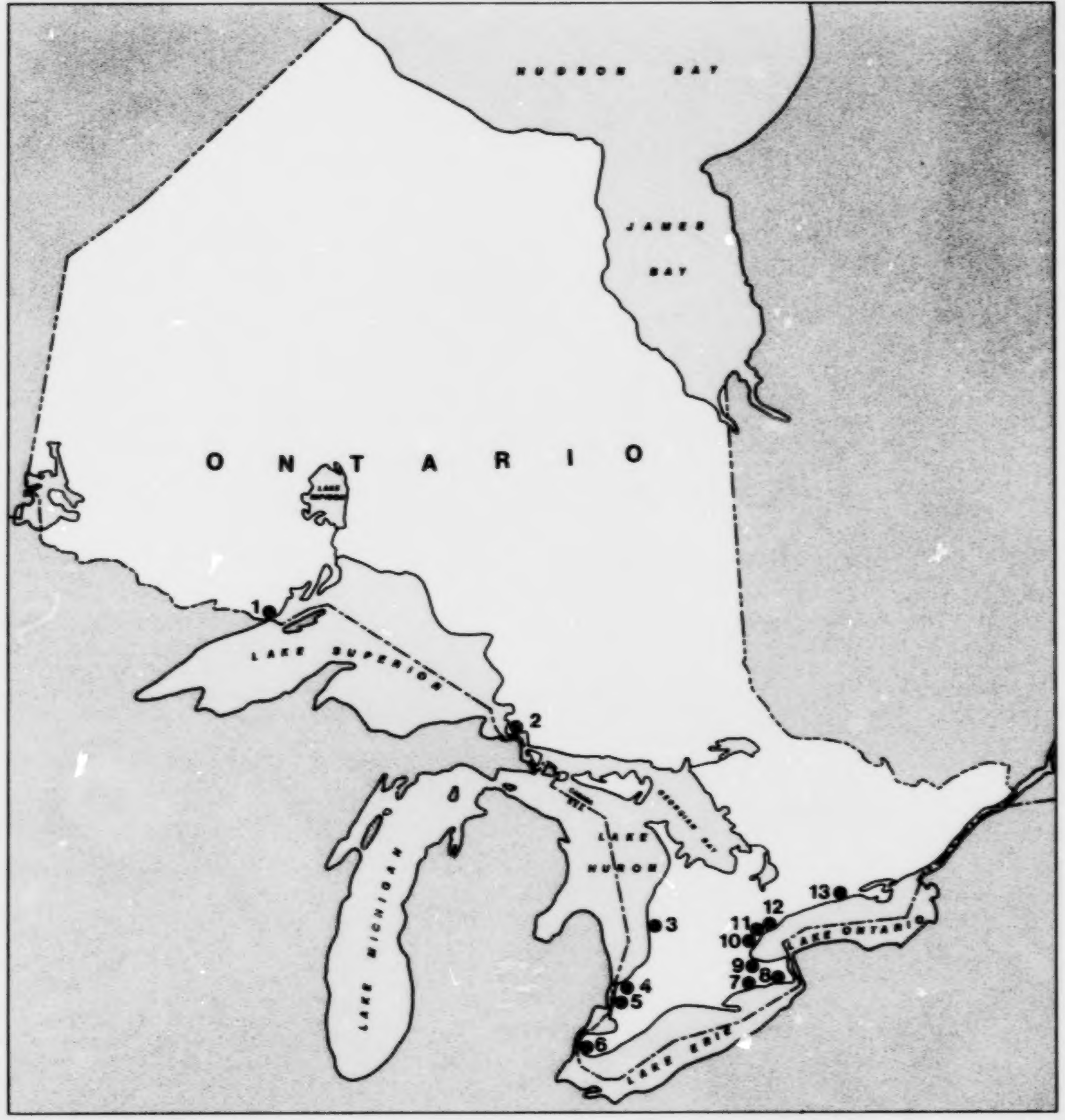
Water levels in Lakes Superior and Ontario are controlled by regulating structures in the St. Mary's and St. Lawrence Rivers. This control also affects water levels in the other lakes to some degree. The controlling depth for navigation reflects the current water level control system for the Great Lakes. A major change in water level control policy would, therefore, have a significant economic impact on commercial shipping on the Great Lakes.

References listed on page 71:

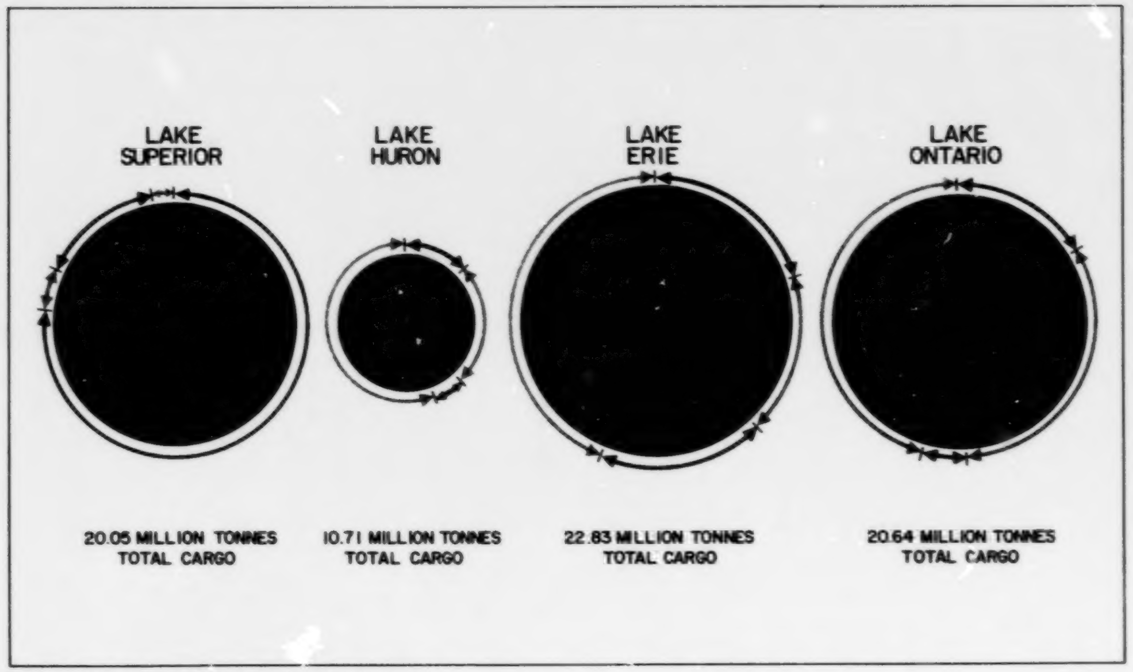
- 22.1 to 22.6 inclusive



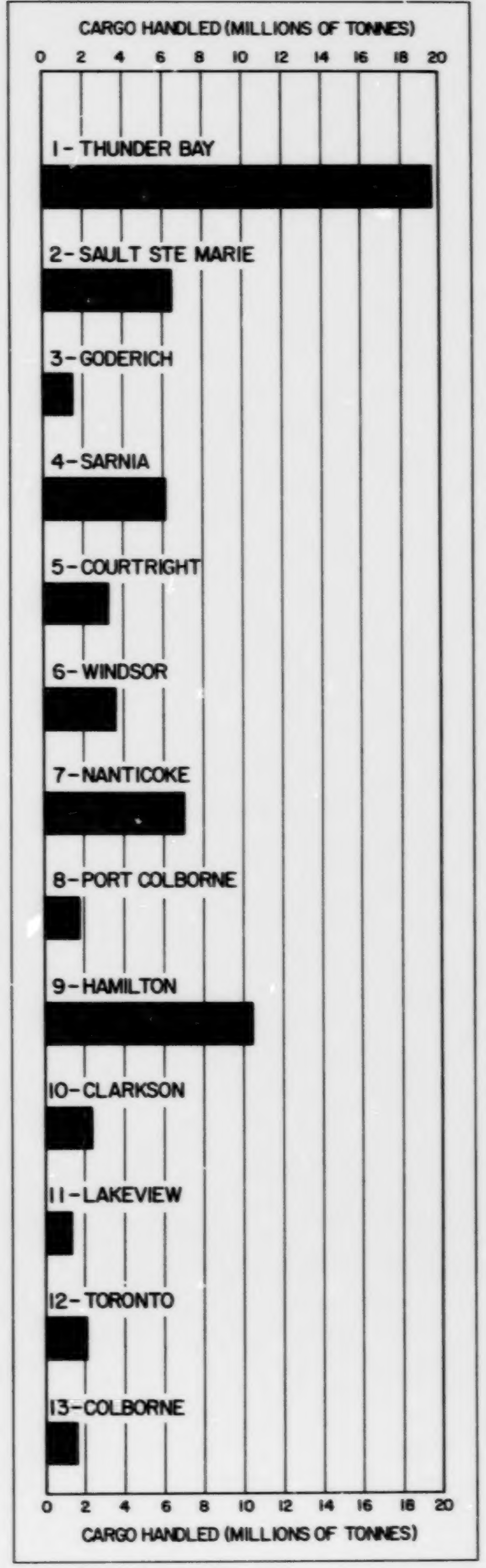
22.1 Cargo Handled According to Wharf Water Depth


HUDSON BAY
JAMES BAY
ONTARIO
LAKE NIPIGON
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ERIE
LAKE ONTARIO
1
2
3
4
5
6
7
8
9
10
11
12
13

22.2 *Port Locations*



22.3 *Cargo Loaded and Unloaded by Lake*



22.4 *Cargo Handled by Port*

■ NATIONAL
■ INTERNATIONAL
■ LOADED
■ UNLOADED

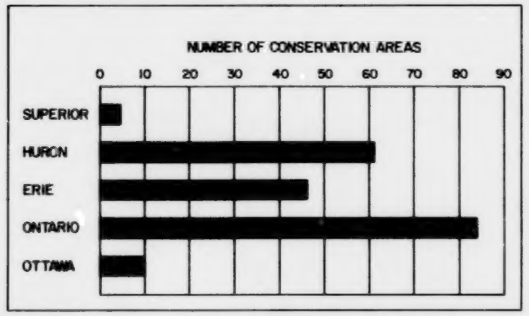
23 – Water-Oriented Recreation and Tourism

While the topic of water-oriented recreation and tourism is presented specifically on these pages, it should be noted that the 2 topics which follow on pages 66 to 69 are also associated with water-oriented recreation and tourism, both physically and economically. The 3 topics should therefore be read in conjunction to obtain a comprehensive view of water-oriented tourism and recreation in Ontario.

Water is abundant everywhere in the province, from calm, clear lakes to rushing streams and impressive waterfalls. The landforms vary from long, sandy beaches to high cliffs and arctic tundra. The Great Lakes provide 5,300 km of mainland shoreline and 4,700 km of island shoreline, most of which is available for recreation, in addition to the shorelines on thousands of inland lakes and rivers. Numerous species of fish, waterfowl and other wildlife are found throughout the province.

Parks are an obvious first choice for many vacationers. There are 4 national parks and 139 provincial parks in Ontario. Many of these are oriented toward water-based recreation, in particular swimming, canoeing, boating and fishing. Those which provide water-based activities are shown on the map opposite.

In addition, particularly in the southern part of the province, 209 conservation areas provide facilities for water-based recreation and are within easy reach of urban areas. These conservation areas are summarized in Figure 23.1.

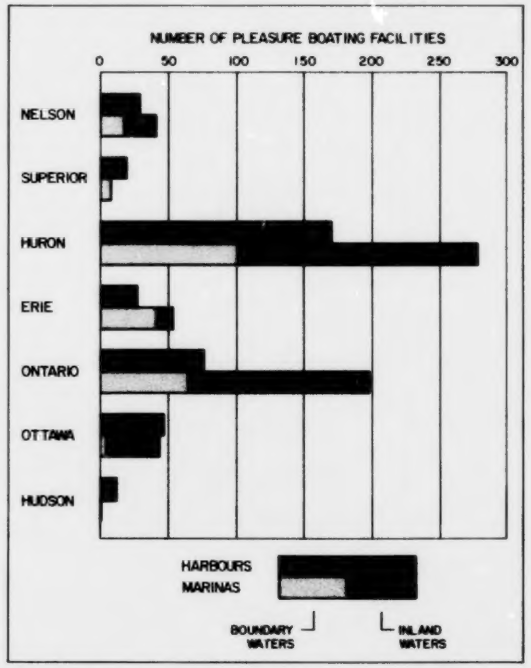


23.1 Conservation Areas With Water-Oriented Facilities by Drainage Basin

Canoeing and boating are important activities in Ontario. Although it is now purely recreational, canoeing was, at one time, the prime mode of transportation. It was ideally suited to a land in which water routes were abundant but had variable navigational conditions, and where land crossings (portages) between water routes were often difficult, precluding the use of a heavier craft. Ontario's currently recognized recreational canoe routes and canoeing areas are shown on the map, together with the locations of whitewater canoeing areas.

The most popular charted waterways for pleasure boating are also shown. In addition to the Great Lakes system, there are 2 canal systems now used primarily by pleasure craft. The Trent-Severn Canal system links Lake Huron with Lake Ontario and the Rideau Canal links Kingston on Lake Ontario with Ottawa on the Ottawa River. Over 240 000 pleasure boats used the Trent-Severn canal system in 1983.

Pleasure boating includes both sailing and power boating. Facilities are provided at federal harbours and privately owned marinas across the province. The numbers and distribution of these facilities, summarized in Figure 23.2, give an indication of the importance of pleasure boating across Ontario.



23.2 Pleasure Boating Facilities by Drainage Basin

With regard to the overall aspects of water-oriented recreation in Ontario, the following observations can be made.

- Water-oriented parks are generally well distributed across the road-accessible portions of the province. A large wilderness park located in the far north on Hudson Bay provides a coastal/tundra preserve of major significance.

- Conservation areas with facilities for water-based recreation are concentrated in the Lakes Ontario, Erie and southern Lake Huron regions in the southern part of the province, and are readily accessible from major urban areas.

- Canoe routes are well distributed over much of the province, with major concentrations in the areas east of Georgian Bay and north of Lakes Huron and Superior. Several significant wilderness routes are available in the far north of the province.

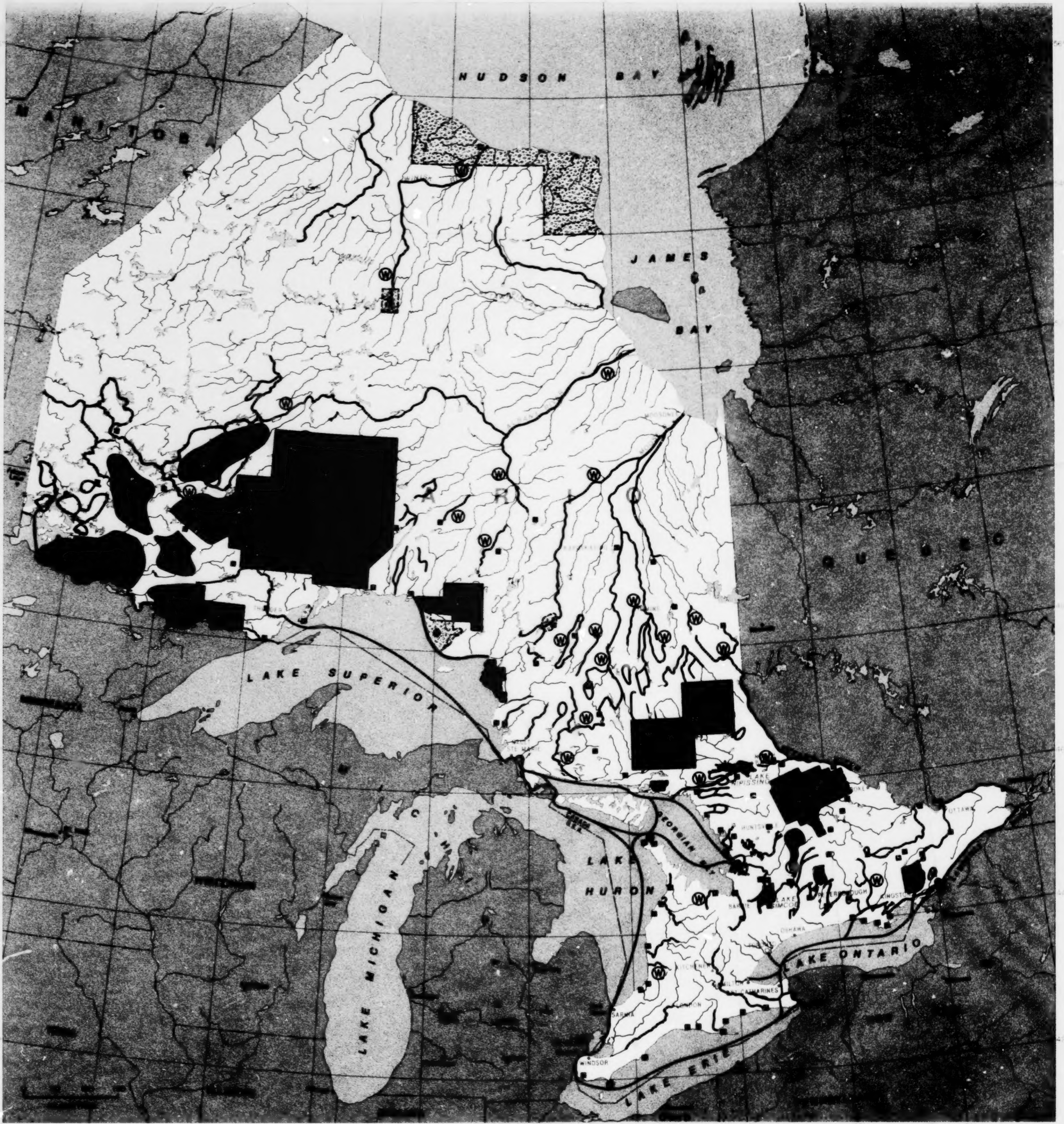
- Pleasure boating facilities are concentrated primarily on the Lake Huron/Georgian Bay shoreline and inland waters, and to a lesser extent on the shoreline and inland waters in the Lake Ontario/St. Lawrence River drainage basins.

The nature and distribution of the many water-based recreation areas in Ontario create a strong focus for tourism. As a result, there is a demand for many types of service facilities including campgrounds, motels, restaurants and stores for boating, diving and fishing equipment and supplies.

References listed on page 71:

- 23.1 to 23.7 inclusive

▨ ● NATIONAL PARK
▨ ▪ PROVINCIAL PARK
■ CANOEING AREA
〜 CANOE ROUTE
Ⓦ WHITE WATER
〜 BOATING WATERWAY


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE NIPISSING
LAKE SIMCOE
LAKE ONTARIO
LAKE ERIE
WINDSOR
SARNIA
KITCHENER
OSHAWA
KINGSTON
OTTAWA

24 – Cottaging

Privately owned cottages are a significant feature of water-based recreation in Ontario. In 1976, approximately 195,000 Ontario households owned vacation homes with an estimated total value of 1 billion dollars. Most cottage owners desire to have direct access to water for all forms of water-based recreation, therefore the impact of cottaging on Ontario's water resources cannot be ignored.

Use was made of a published study and related information to present cottaging density on a county basis in southern Ontario, for the year 1979, as shown on the map opposite. The cottaging dominance of the counties south and east of Georgian Bay is evident. A more detailed analysis of cottaging would show a concentration of cottages on major waterways and shorelines of the lower Great Lakes.

Since the availability of new cottaging areas in southern Ontario is declining, the northern and eastern parts of the province are now experiencing cottaging growth. Northern Ontario counties, however, are not shown on the map since the average density of cottages is less than 0.1 per km^2 and there is a limited cottage inventory. Some significant cottaging growth has developed in the Lake of the Woods area, along the north shore of Lake Huron and northeast of Sudbury.

In the northern part of the province, hunting and fishing camps have been developed on inland lakes and rivers where the access is generally by float- or ski-equipped planes.

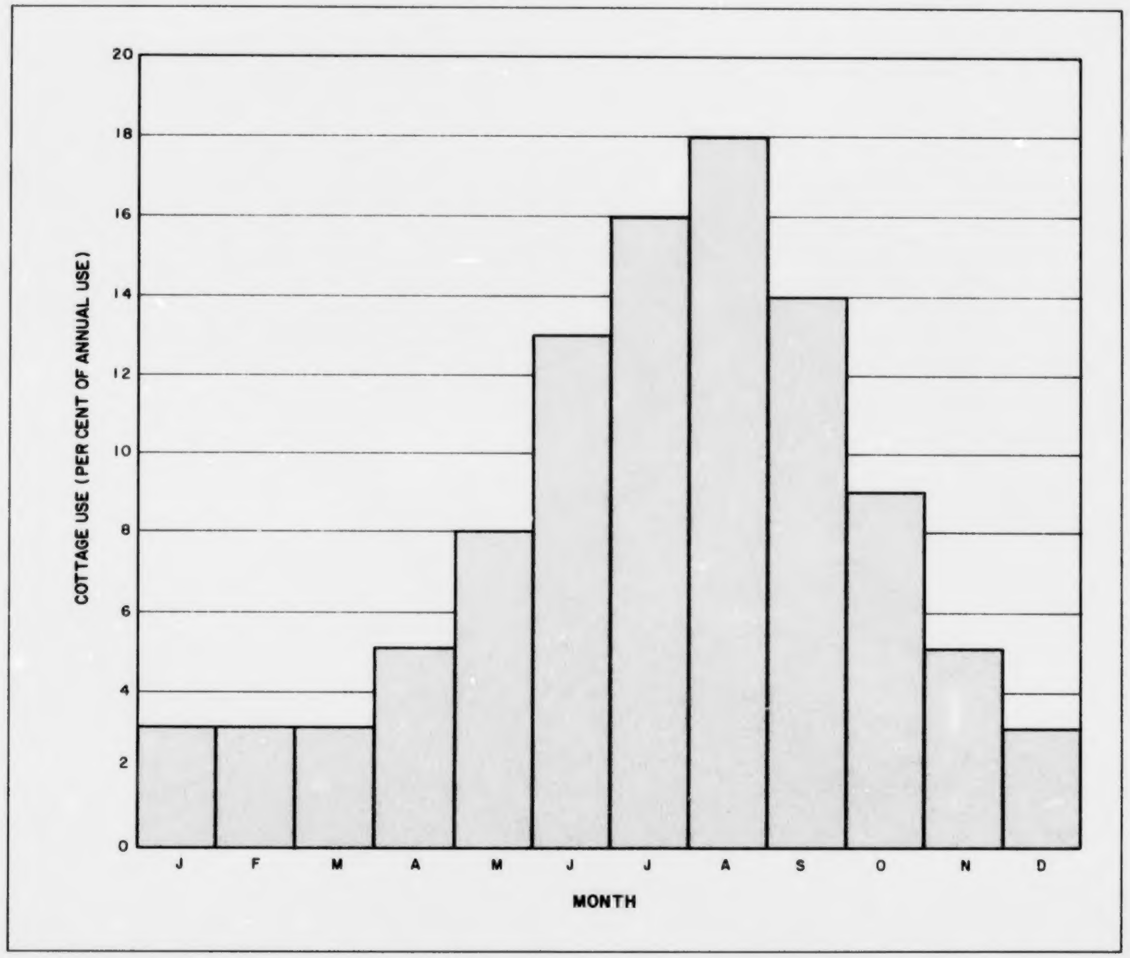
The extensive development of cottages and docking facilities in the province requires the careful control of lake levels, particularly southeast of Georgian Bay, and the maintenance and operation of approximately 300 dams across the province.

The sharp climatic distinctions between seasons in Ontario results in cottaging being a predominantly summer activity. The published study referred to above compiled cottage use on a monthly basis as summarized in Figure 24.1. Eighteen per cent of annual cottage use occurs in August, with June, July and September ranging from 13 to 16 per cent. It is important to note that cottages are used to a limited extent throughout the winter months.

Cottaging creates a seasonal need for various kinds of support services and retail outlets which is important to the province's economy. This importance will increase as cottaging growth continues and winter use is extended.

References listed on page 71:

- 24.1 to 24.3 inclusive



24.1 Monthly Cottage Use

COTTAGE DENSITY
(No./km^2)

⬚ LESS THAN 0.1

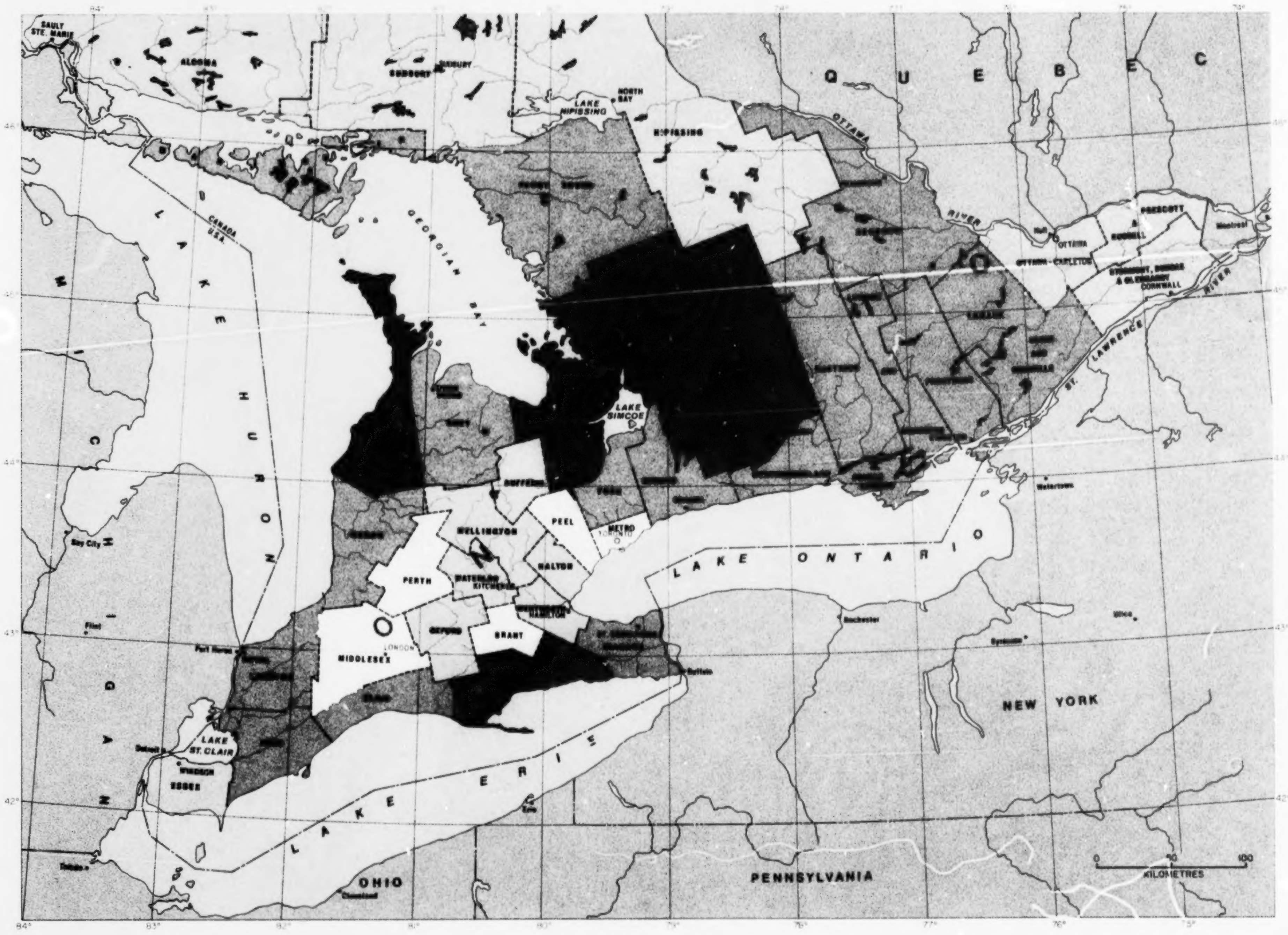
░ 0.1 - 1

▒ 1 - 3

▓ 3-5

■ MORE THAN 5

----- COUNTY BOUNDARY


SAULT STE. MARIE
ALGOMA
SUDBURY
SUDBURY
LAKE NIPISSING
NORTH BAY
NIPISSING
Q U E B E C
OTTAWA RIVER
GEORGIAN BAY
L A K E H U R O N
CANADA
USA
M I C H I G A N
Bay City
Flint
Port Huron
Detroit
LAKE ST. CLAIR
WINDSOR
ESSEX
LAKE SIMCOE
DUFFERIN
PEEL
METRO
TORONTO
WELLINGTON
HALTON
PERTH
WATERLOO
KITCHENER
HAMILTON
OXFORD
BRANT
MIDDLESEX
LONDON
O N T A R I O
Buffalo
L A K E O N T A R I O
L A K E E R I E
Erie
OHIO
Cleveland
Toledo
Rochester
Syracuse
Utica
Watertown
NEW YORK
PENNSYLVANIA
OTTAWA
OTTAWA - CARLETON
PRESCOTT & RUSSELL
STORMONT, DUNDAS & GLENGARRY
CORNWALL
Hull
Montreal
ST. LAWRENCE RIVER
0
50
100
KILOMETRES
84°
83°
82°
81°
80°
79°
78°
77°
76°
75°
74°
46°
45°
44°
43°
42°

25 – Fish and Wildlife

Fishing in Ontario is of considerable importance both commercially and recreationally. In 1980, some 27 000 tonnes of fish were landed by the province's commercial fishing industry, and an estimated 95 million fish were caught by sports fishing enthusiasts from both inside and outside the province.

A published study of sport fishermen and statistics on commercial fishing were used to derive the information shown in Figure 25.1. The importance of Lake Erie to the commercial fishing industry is evident. For sport fishing, the waters inland from the Great Lakes shoreline in southern Ontario are the most important, followed by Lake Erie and the northern inland waters.

Ontario's commercial fishing landings were 41 per cent of the total landings from the Great Lakes in 1977. If Lake Michigan fish landings are excluded, since no landings from that lake are recorded for Ontario, Ontario's landings represented 74 per cent of the landings from the remaining Great Lakes in that year. On an individual lake basis, Ontario landings varied from 46 per cent of the total for Lake Superior to 92 per cent of the total for Lake Ontario.

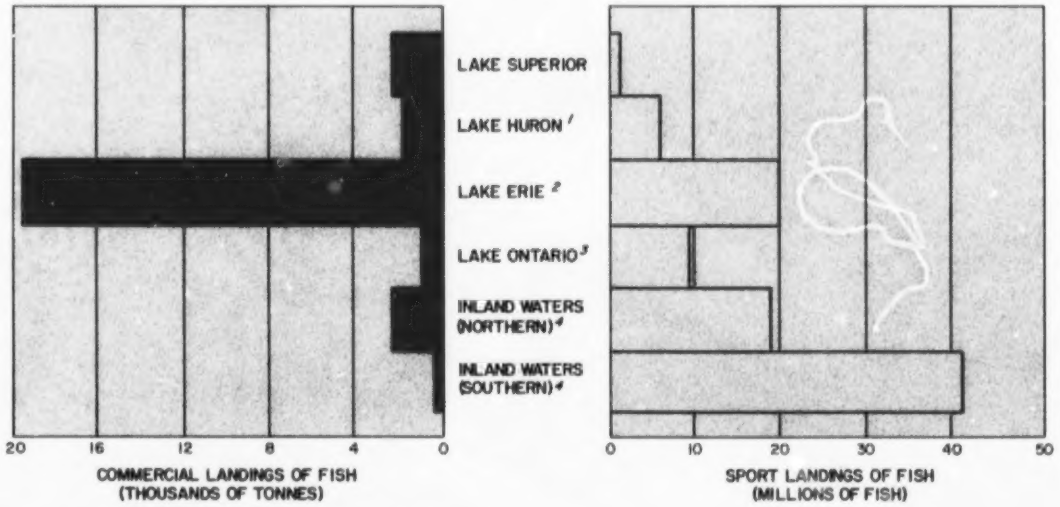
Ontario's waterfowl habitat is closely linked to the wetland areas of the province, which may be described as highly saturated areas of land. Wetlands include bogs, marshes, swamps and shallow open water. The map opposite shows the distribution of wetlands across the province, according to the percentage of total area occupied by wetlands. The far north of the province is clearly seen to be the dominant wetland area of Ontario.

Classification of the importance of any area to waterfowl takes account of the specific requirements to support waterfowl and the capability of the area to meet these requirements. Availability of appropriate food and water, suitable vegetation or landforms and sufficient space is the prime consideration. Land capability mapping was prepared on this basis for southern Ontario and parts of Northern Ontario in 1977, and those areas classified as having significant importance for migration or for wintering waterfowl have also been shown on the map. The northern and eastern shorelines of the North Channel, the Georgian Bay portions of Lake Huron, together with the northern shoreline of the St. Lawrence River, are the most significant areas in this classification.

Duck hunting is a very important recreational activity in wetland areas throughout the province, attracting hunters from both inside and outside the province.

References listed on page 71:

- 25.1 to 25.5 inclusive

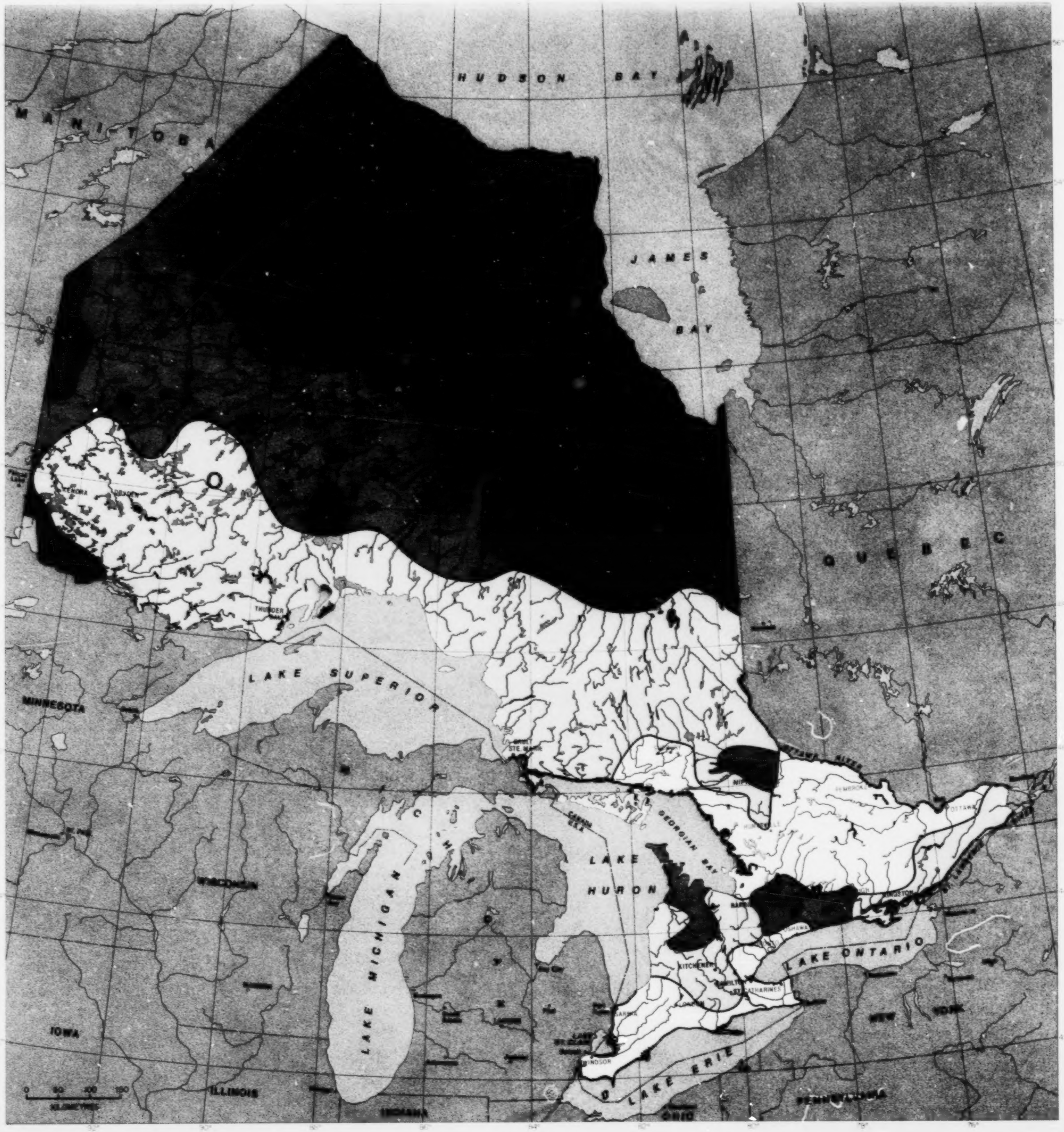


1. INCLUDES GEORGIAN BAY, NORTH CHANNEL AND ST MARYS RIVER
2. INCLUDES LAKE ST. CLAIR, ST. CLAIR RIVER, DETROIT RIVER AND NIAGARA RIVER
3. INCLUDES ST. LAWRENCE RIVER IN ONTARIO
4. DIVISION BETWEEN NORTH AND SOUTH ONTARIO TAKEN AT FRENCH RIVER, LAKE NIPISSING AND MATTAWA RIVER

25.1 Commercial and Sport Fish Landings

AREA OCCUPIED BY WETLANDS
(% OF TOTAL AREA)

□ 0 - 5
░ 5 - 25
▒ 25 - 50
▓ 50 - 75
█ 75 - 100
— AREAS HAVING SIGNIFICANT IMPORTANCE FOR MIGRATION OR FOR WINTERING WATERFOWL


HUDSON BAY
MANITOBA
JAMES BAY
QUEBEC
O
KENORA
DRYDEN
THUNDER BAY
LAKE SUPERIOR
MINNESOTA
SAULT STE. MARIE
OTTAWA RIVER
NIPISSING
PEMBROKE
OTTAWA
HUNTSVILLE
GEORGIAN BAY
CANADA U.S.A.
LAKE HURON
BARRIE
KINGSTON
ST. LAWRENCE
OSHAWA
LAKE ONTARIO
KITCHENER
HAMILTON
ST. CATHARINES
LONDON
SARNIA
LAKE ST. CLAIR
WINDSOR
LAKE ERIE
LAKE MICHIGAN
WISCONSIN
IOWA
ILLINOIS
INDIANA
OHIO
NEW YORK
PENNSYLVANIA
0 50 100 150
KILOMETRES

26 – Ontario's Future Use of Water

In the previous pages of this section, current water use in Ontario has been reviewed and estimates of future "withdrawal" water use have been presented. The recently published studies by Environment Canada and the International Great Lakes Diversions and Consumptive Uses Study Board indicate that future demand for Ontario's water will increase by about 5 per cent every year. Estimates of future consumption of water are said to be sufficient to lower the level of some of the Great Lakes by 12 to 34 cm (4.7 in. to 13.4 in.) in 50 years time. This type of reduction could have significant economic consequences.

Future water demand figures for other areas of Canada such as the southern portions of the prairie provinces indicate that the available reliable water supply is barely adequate to meet present demands. The extent to which water conservation techniques may reduce future demand are not known. However, some reduction should be possible given the recent success of energy conservation measures in reducing energy consumption.

Published estimates of future "in situ" water use are not extensive. However, a consideration of past and present trends has led to some indication of the expected future use of "in situ" water.

In the case of hydroelectric power generation, the considerable extent of undeveloped capacity in Ontario has been discussed. Between 1975 and 1982 there was only a minimal increase in installed hydroelectric generating capacity, and energy production actually dropped by a small amount. This is in sharp contrast to the very substantial increases in thermal power installed capacity and energy production over the same period. According to a report by Energy, Mines and Resources Canada, no further increases in hydroelectric power generating capacity in the province are proposed before 1993.

As for commercial shipping, a recent study by Acres Consulting Services/Data Resources forecasts total shipping increases of 40 to 50 per cent between 1980 and 2000.

Ontario's population is forecast to increase by about 30 per cent between 1981 and 2000. Consequently, water-based recreational activities can be expected to increase over this period by about 30 per cent. Future water-oriented recreational activity is probably estimated most simply by relating it directly to population, but this assumes negligible changes both in leisure time per person and in current patterns of use of recreational facilities.

Since sport fishing is a recreational activity, the same considerations would lead to a predicted 30 per cent increase in sport fishing activity by the year 2000. In the case of commercial fishing, some expansion of the industry can be expected between 1980 and 2000, based on extrapolations of historic data compiled by the Ontario Ministry of Natural Resources.

In spite of the fact that improved treatment of wastewater prior to discharge to receiving water bodies will likely occur, the "in situ" use of surface water for waste assimilation can be expected to continue in the future with substantial population growth. Urban development will inevitably place new pressures on local receiving streams, particularly those with limited assimilative capacities. This will require appropriate and efficient wastewater management practices, so as to ensure that surface water of similar quality is available for all "withdrawal" and "in situ" uses.

References listed on page 71:

- 26.1 to 26.8 inclusive

List of References

18.1 Environment Canada, 1982
National Inventory of Municipal Waterworks
and Wastewater Systems in Canada 1981

18.2 Statistics Canada, 1982
1981 Census of Canada, Census Divisions,
Population, Occupied Private Dwellings,
Private Households, Census Families
in Private Households, Selected
Characteristics

18.3 Environment Canada, 1979
Consumptive Water Use in the Canadian
Section of the Great Lakes Basin,
1975 - 2035

18.4 Montreal Engineering Company
Limited, 1972
Report for Canada Department of
the Environment
Estimates of Current Water Use in Canada

19.1 See 18.1 above.

19.2 Environment Canada, 1980
Historical Streamflow Summary -
Ontario to 1979

19.3 Ontario Ministry of the Environment, 1973
Southern Ontario Drainage Basins
(map)

20.1 International Great Lakes Diversions and
Consumptive Uses Study Board, 1981
Great Lakes Diversions and Consumptive
Uses, Annex F, Consumptive Water Use,
Report to the International Joint
Commission

20.2 See 18.3 above.

20.3 See 18.4 above.

20.4 Ontario Ministry of the Environment, 1983
Permits to Take Water Data

20.5 Energy, Mines and Resources Canada,
1982
Electric Power in Canada 1982

20.6 Energy, Mines and Resources Canada,
1975
Electric Power in Canada 1975
(including map)

20.7 Energy, Mines and Resources Canada,
1981
Ontario, Main Electric Transmission
Systems and Principal Power Generating
Developments
(map)

20.8 Environment Canada, unpublished
1976 Industrial Water Use Survey Results

21.1 Ontario Hydro, 1982
Hydraulic Power Resources of the Province
of Ontario, Inventory Report 1982
(including maps)

21.2 See 20.5 above.

21.3 Fisheries and Environment Canada, 1977
Ontario, Active Hydrometric Stations
(map)

22.1 Statistics Canada, 1982
Coastwise Shipping Statistics, 1981

22.2 Statistics Canada, 1983
International Seaborne Shipping Port
Statistics, 1981

22.3 Fisheries and Oceans Canada, 1982
Sailing Directions, Great Lakes
Ninth Edition
Volume 1

22.4 Fisheries and Oceans Canada, 1980
Sailing Directions, Great Lakes
Fifth Edition
Volume 2

22.5 1982 Canadian Ports and Seaway
Directory, 1982
Southam Business Publications

22.6 International Great Lakes Diversions
and Consumptive Uses Study
Board, 1981
Great Lakes Diversions and Consumptive
Uses, Report to the International
Joint Commission

23.1 Parks Canada, 1982
National Parks - A Brief Guide

23.2 Ontario Ministry of Natural Resources, 1981
Ontario Provincial Parks

23.3 Ontario Ministry of Natural Resources
Guide to Conservation Areas
(map)

23.4 Ontario Ministry of Natural Resources, 1981
Canoe Routes of Ontario
(including map)

23.5 Fisheries and Oceans Canada, 1983
Guide to Federal Harbours, Ontario
(map)

23.6 Ontario Ministry of Tourism and Recreation,
1983
Boating

23.7 Ontario Ministry of Transportation and
Communications, 1982 - 1983
Official Road Map, Ontario, Canada

24.1 Ontario Ministry of Natural Resources, 1979
Cottages and Cottagers

24.2 Ontario Ministry of Municipal Affairs
and Housing
Municipal Directory 1983

24.3 See 23.7 above.

25.1 Ontario Ministry of Natural Resources
Ontario Commercial Fish Industry, Statistics
on Landings 1976 - 1980
Supplemented by update for 1981 and
1982

25.2 Ontario Ministry of Natural Resources
1980 Surveys of Ontario's Resident and
Non-Resident Sport Fishermen

25.3 See 22.6 above.

25.4 Environment Canada, 1981
Wetlands of Canada, Distribution of
Wetlands
(map)

25.5 Environment Canada, 1977
Canada Land Inventory, 1:100,000 Map
Series Ontario, Land Capability for
Wildlife - Waterfowl

26.1 See 20.5 above.

26.2 See 20.6 above.

26.3 Provincial Great Lakes/Seaway Task
Force, 1981
The Great Lakes/Seaway: Setting a Course
for the '80's

26.4 Acres Consulting Services Limited/Data
Resources, Inc., 1982
Seaway Commodity Flow Forecast
1980 to 2000
Executive Summary

26.5 See 20.1 above.

26.6 See 25.1 above.

26.7 See 22.6 above.

26.8 See 18.3 above.

POOR

QUALITY

ORIGINAL